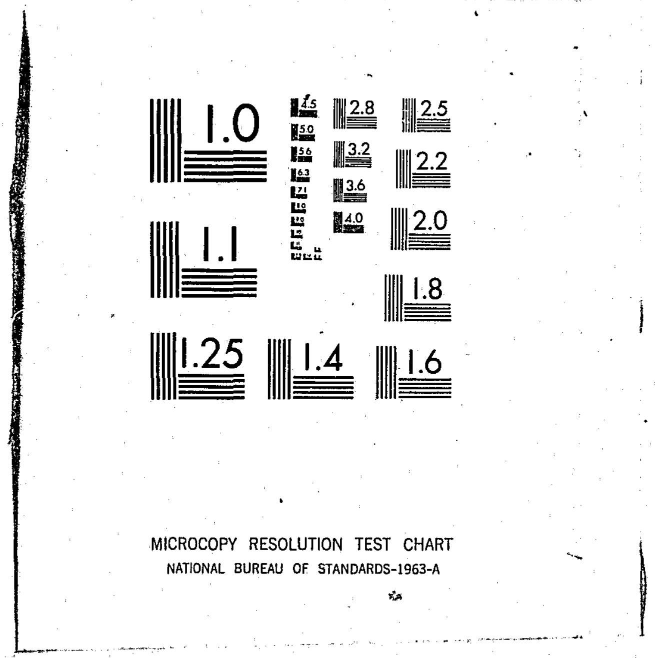

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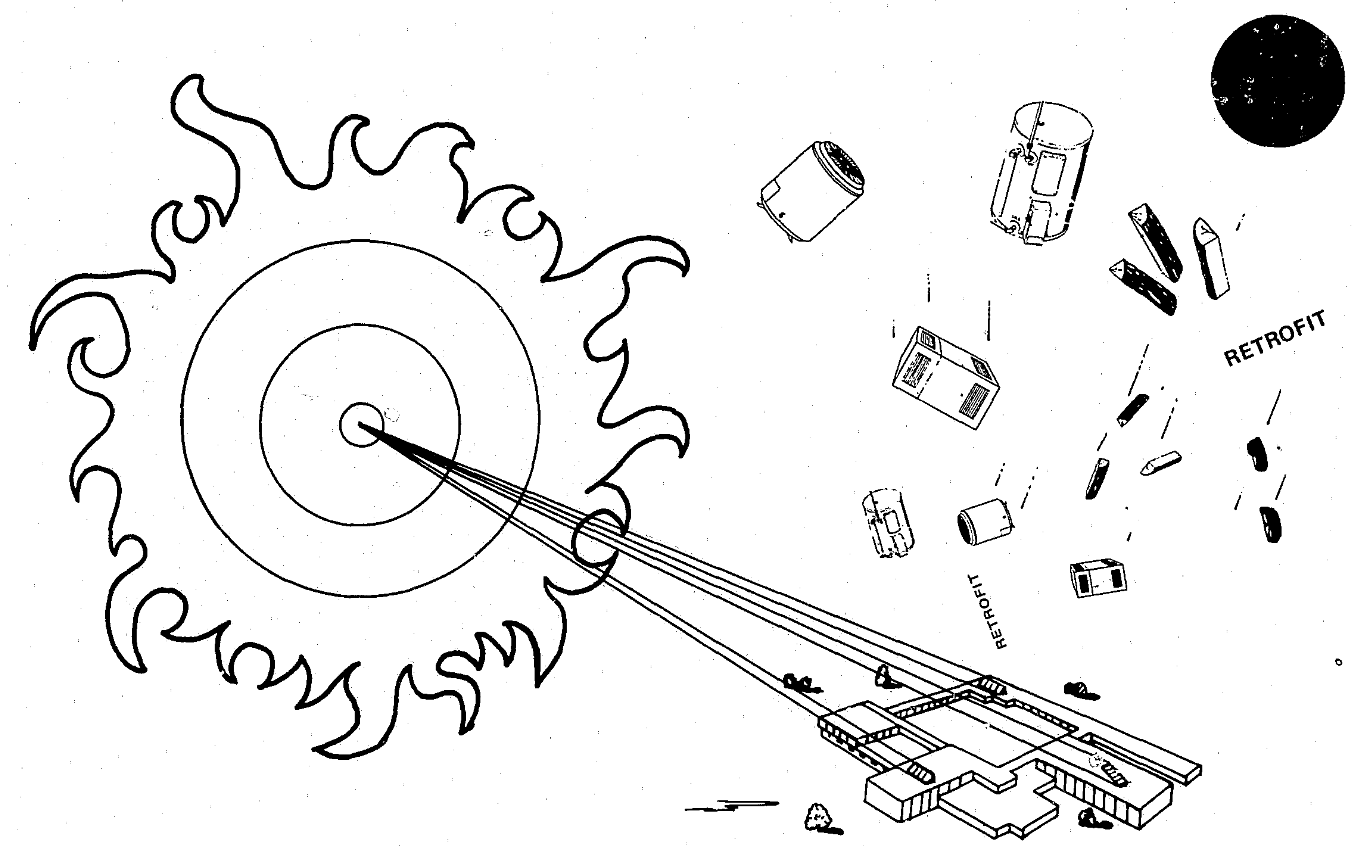

HANDBOOK FOR ENERGY CONSERVATION IN CORRECTIONAL FACILITIES

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LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
U.S. DEPARTMENT OF JUSTICE

ENFORCEMENT ASSISTANCE ADMINISTRATION
DEPARTMENT OF JUSTICE

HANDBOOK FOR

ENERGY CONSERVATION IN CORRECTIONAL FACILITIES

Prepared for
Law Enforcement Assistance Administration
U.S. Department of Justice
Washington, DC 20531

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FOREWORD

This handbook has been carefully designed to enhance and simplify the work of correctional facility managers and engineers in the analysis and modification of existing structures to reduce energy use and costs. The handbook offers a field-tested approach to identifying, analyzing, and recommending action on a wide range of options available to reduce energy use in most existing buildings. It provides a step-by-step methodology for assessing and improving the year-round energy performance of buildings as well as a series of forms and charts designed to assist correctional facility personnel in attaining and maintaining this improved performance.

Energy conservation is no longer a program which can be ignored by correctional facility managers. The time has come for vigorous and positive action in this area. Look for your efforts and initiatives to pay for themselves rather than for grants and monies to pay for your efforts. This handbook is a major part of the overall program. Use it wisely and aggressively.

David S Graves

DAVID S. GRAVES
Corrections Specialist
Corrections Division
Office of Criminal Justice Programs
Law Enforcement Assistance Administration

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PREFACE AND ACKNOWLEDGMENTS

This handbook was prepared as a joint venture by Unified Industries Incorporated of Springfield, Virginia and JRB Associates, Incorporated, of McLean, Virginia, under Small Business Administration Contract Number 3-4-0-8(a)-C-2074 administered by the U.S. Department of Justice, Office of Justice Assistance, Research and Statistics. This handbook incorporates data, information and suggestions that have been developed over a period of several years by Unified Industries Incorporated, JRB Associates, Incorporated, and various Governmental agencies. The information contained in this handbook has been subjected to extensive field testing and is accordingly a practical tool for energy conservation and management in correctional facilities.

Unified Industries Incorporated and JRB Associates, Incorporated, wish to acknowledge the cooperation and assistance in the preparation of this handbook rendered by the Law Enforcement Assistance Administration and particularly by Mr. David S. Graves, Office of Criminal Justice Programs, whose professional guidance in the intricacies of operation and management of correctional facilities was invaluable. Additionally, acknowledgment is made to state correctional and energy directors for energy consumption data submitted on state correctional facilities and to Mr. Robert Buchanan, President, Correctional Services Group, Incorporated, for his detailed contribution on special considerations that pertain to energy conservation in correctional facilities.

If you have any comments for improvement of this handbook or questions please contact Unified Industries Incorporated, 6551 Loisdale Court, Springfield, Virginia 22150 or telephone (703) 922-9800, Mr. Alfred Paradise.

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SUMMARY

The Handbook for Energy Conservation in Correctional Facilities describes energy use, cost trends and energy conservation potential in correctional facilities. Based upon the initial reactions and input received from the field, the handbook has been divided into two sections. Section One, consisting of Chapters I through III, has been designed for the administrator or program developer. The text is nontechnical in content, giving an overview of how to task-organize for energy conservation in correctional facilities from a managerial viewpoint. Section Two, consisting of Chapters IV through VIII, has been designed for use by the facility engineer or plant maintenance supervisor. It covers the technical and engineering aspects of how to evaluate and apply energy conservation opportunities. This section does not require any special training or background for application. The material is presented in a sequential manner so as to be understood by the decision-making manager as well as the hands-on engineer. It is not necessary to absorb the entire text in order to effectively use the handbook. Apply the methodology as explained, and take a course of action as appropriate; used in this manner, the handbook becomes the energy conservation tool that it was intended to be.

Introduction

Soaring costs, higher use and dwindling resources have made energy conservation in itself a new alternative "source" of energy. The potential for conservation is great, especially in the area of buildings, since many of the existing ones were not designed with conservation in mind. Most of our correctional facilities are composed of buildings with antiquated heating and cooling systems, poor ventilation and a general lack of application of any conservation principles. Over the next few decades, new buildings with modern, energy-efficient support systems are not likely to replace the old ones. Proper physical plant maintenance which includes effective energy resource management are and will continue to be critical issues for every correctional facility manager.

Program Development and Management

A commodity as essential and as costly as energy must be controlled in a systematic cost-effective manner. This can best be accomplished through the development of a well planned energy management program.

An indispensible ingredient in program development is the commitment of top management and its representation in the early formation of the energy management team.

The team begins its effort by establishing realistic goals and objectives and considering alternative strategies for achieving these goals. The strategy adopted should be one that moves from the most elementary of conservation steps to levels of increasing sophistication. The life of the budget as it relates to energy conservation is also important. Since most budgets are prepared annually, it is difficult to integrate them with a long-range energy plan that spans 5 or 10 years. Experience has demonstrated that long-term projects, such as an in-depth energy conservation

program, may fail if the needed funds are not forthcoming. With this in mind, the long-range fiscal needs of the energy program must be made compatible with the annual budget. Communication and motivation are essential for the successful implementation of the energy conservation program. Once the program has been developed, it is appropriate to publicize it. Further impetus to the energy conservation program may be found in the employment of resident labor in the manufacture/assemblage of energy-saving equipment. The need to provide meaningful activities for prisoners, and the urgent need to develop more economical energy sources, have arrived almost simultaneously for correctional administrators. Intertwined with all of the above essential elements of a successful energy conservation program are the provision of humane care and custody of inmates and a safe working environment for corrections personnel.

Once a correctional facility's program for energy conservation has been organized, the facility should be surveyed periodically to determine total energy use and energy use patterns. A survey consists of an audit of energy consumption records and a detailed physical examination of the facility itself.

Survey Methodology

The method employed for identifying retrofit projects parallels that of a full-scale engineering survey but is far less comprehensive, for its purpose is only to identify sound retrofit projects and provide approximate measures of their relative merits for budgetary planning. The survey method steps are: collecting energy use data, categorizing buildings, identifying retrofit options, and evaluating and ranking retrofit projects. The worksheets for accomplishing these steps may be found in Appendix A.

Estimating Energy Use in Buildings

The determination of building energy use may or may not be an easy task. It is dependent upon such factors as available metering, the quantity and quality of fuel records and the effectiveness of the preventive maintenance program already in existence at the site.

Basic facts about the building, its site and its function should be assembled. Fuel bills associated with the building should be obtained. If fuel data is not available, this handbook outlines simple procedures to follow in arriving at the estimates needed to analyze energy conserving options. Once this data has been gathered, it is then possible to estimate the amount of energy consumed by each system in the building and the potential energy and cost savings to be derived from various Energy Conservation Opportunities (ECO's).

Energy Conservation Opportunities

Anything which uses or causes energy to be used in a facility represents a potential for energy conservation; whether that be a poorly insulated duct, lights too bright for the functions they are lighting, or south-facing windows unshaded in the summer. By the time the survey phase of the energy program for a correctional facility has been completed, a list of potential ECO's will have been accumulated. It is vital to the energy

conservation program that both the correctional facility staff and the inmate population be motivated toward recognizing and implementing ECO's. A program without their support will achieve only a segment of its designed objectives.

The simple payback period (SPP) is the key to the value of an ECO. It is easily calculated as outlined in the text of this document. As a general rule, a payback period beyond 10 years is normally considered excessive and therefore an ECO not worthy of further consideration. All ECO's should be compared based on their payback period with priority of action based on SPP.

All energy using systems should be analyzed as potential sources for ECO's in the form of retrofit options. These include architectural, ventilation, cooling, lighting, heating and water heating. Examples of the retrofit options most commonly found to pay back within 5 years for each of the above systems are outlined in detail in the main body of this handbook.

Supplemental Suggested Energy Conservation Options

In the previous chapters of the handbook, ECO's were presented which are generally considered more economically feasible in correctional facilities. Other possible energy conservation opportunities exist which may also be viable for your particular situation. They are those options which are normally not justifiable except under special conditions and those whose effects are very difficult to measure directly. The text of these options does not provide sufficient information for you to perform actual savings calculations. However, if one or more appear to have some relevance to your situation, assistance in making estimates may be obtained either from a local distributor, manufacturer's representative or your state energy office.

Operation and Maintenance Procedures and Conservation Practices

Maintaining a building's structure and equipment is a very effective method of reducing its energy use. Heating, ventilating and cooling systems usually account for the largest portion of energy use in typical nonindustrial correctional buildings, with hot water systems not far behind. It is especially important that these major energy systems be operated and maintained in a manner that will maximize their efficiency.

A significant amount of energy can also be saved by daily conservation practices which not only cut down on energy use but also make the most of the energy that is used. The areas most conducive to these practices are housing, offices, food service, and public use. Unlike major energy saving measures requiring retrofit, implementing these conservation procedures and practices requires the participation of the full staff at the correctional facility. Assistance should be provided by facility management through policies supporting these conservation practices.

Alternative Energy Sources

Alternative energy sources promise to be, once again, the most important form of raw power used. Most of the new ways to produce power are a rediscovery of the old proven methods that were abandoned after the discovery of cheap oil and natural gas. Now that these fuel supplies are dwindling and their prices are increasing, it has become cost-effective to consider using alternative energy sources.

The most common of these alternative energy sources are solar thermal, biomass, wind power, hydropower, photovoltaics and cogeneration. Solar thermal and biomass offer the greatest potential for utilization by a correctional facility and both systems are, in fact, being employed by correctional facilities at several locations throughout the country.

HANDBOOK FOR ENERGY CONSERVATION IN CORRECTIONAL FACILITIES

CHAPTER I. INTRODUCTION

A. Energy Conservation in Correctional Facilities

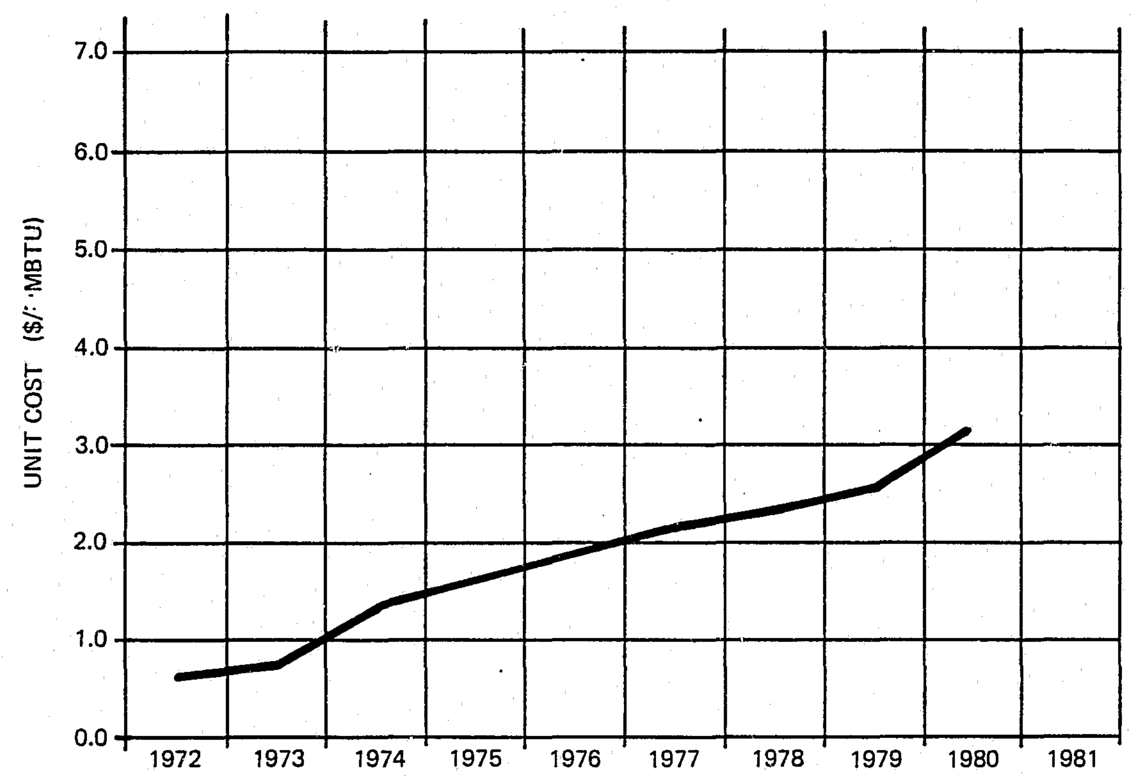
Until recently, energy was taken for granted as being abundant, available, and cheap. It was, and, in some cases still is, the forgotten resource in managing a correctional environment. Whenever a decision was made regarding the acquisition or alteration of a new system or piece of equipment, management's goal was to minimize the initial capital costs while accepting the resultant operating (energy-using) costs. Needless to say, this strategy is no longer acceptable.

Soaring costs, higher use, and dwindling resources have made energy conservation in itself a new alternative "source" of energy. The potential for conservation is great, especially in the area of buildings, since many of the existing ones were not designed with conservation in mind. Most of our correctional facilities are composed of buildings with antiquated heating and cooling systems, poor ventilation, and a general lack of any conservation principles. Over the next few decades, new buildings with modern, energy-efficient support systems are not likely to replace the old ones. Thus, energy conservation indeed becomes a key for survival for the correctional facility manager.

1. Energy use and cost trends in correctional facilities. Because a typical correctional facility consists of one or more buildings, each using conventional energy sources, it is safe to compare the energy use and cost trends of the correctional environment with those experienced by the nation as a whole. These trends are the key variables in evaluating any conservation program.

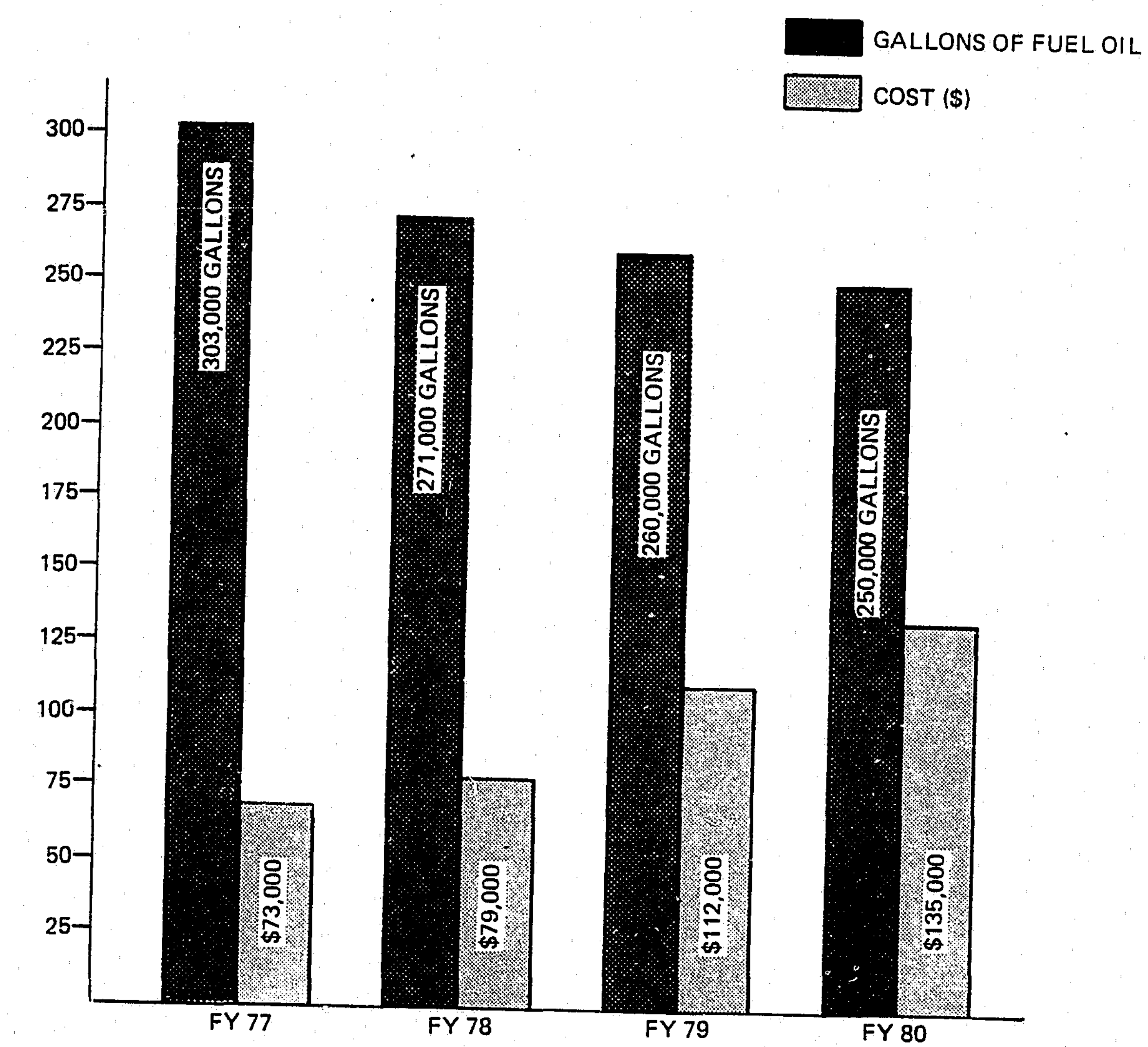
Figure 1-1 shows that the cost of energy has increased steadily since 1973.

Figure 1-1. Costs of all Energy Consumed in the U.S.



The problem, though, in staying within budget constraints is that energy costs money, and the prices are forever rising. These upward cost trends are offsetting reductions in energy use. Take, for example, the State Prison of New Hampshire (See figure 1-2). Over the last 3 years, this facility has actually cut fuel oil consumption by 53,000 gallons, or 17 percent. However, the reduction in usage has been offset by a 179 percent increase in the price of fuel oil, resulting in an overall dollar increase of $62,000.

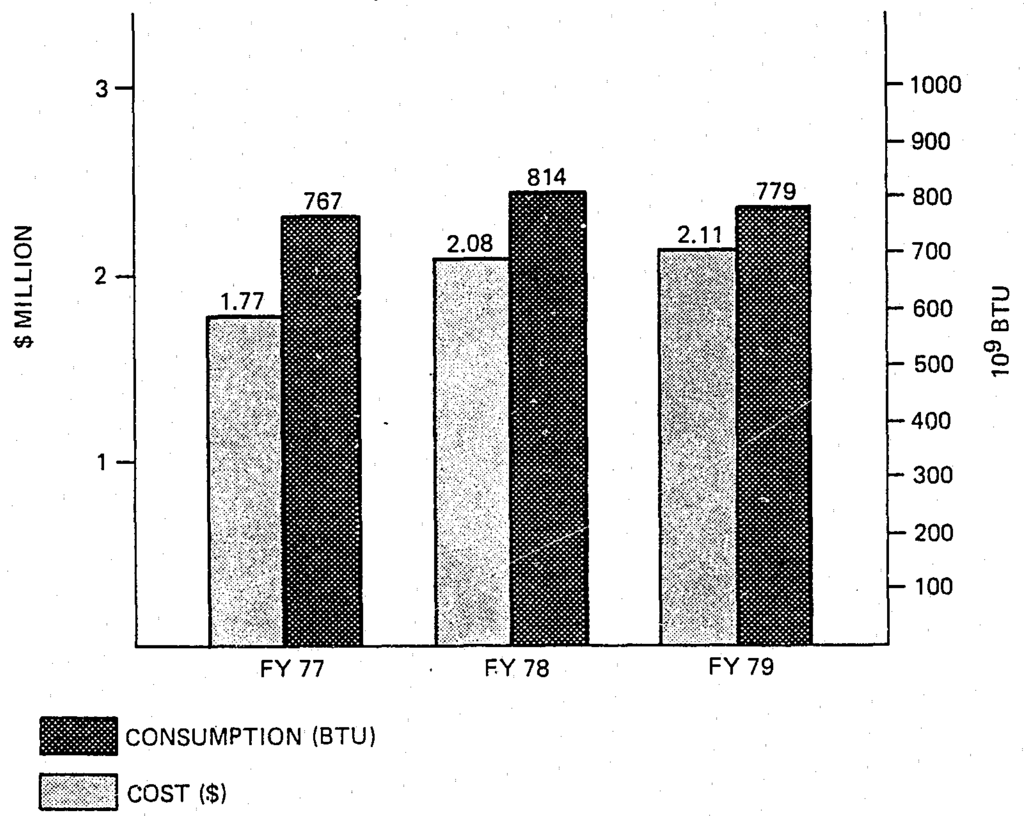
Figure 1-2. New Hampshire State Prison Fuel Oil Consumption and Cost FY 1977 - FY 1980



(Note: The price per gallon of fuel oil increased from $0.24 to $0.67 during this time period)

The Lorton Penitentiary of Washington, D.C. suffers a similar problem. The amount of Btu's consumed has remained fairly constant. The energy costs, however, have soared over the $2,000,000-per-year mark, a 19 percent increase. (See figure 1-3)

Figure 1-3. Washington, D.C. (Lorton) Consumption and Cost Trends FY 1977 - FY 1979

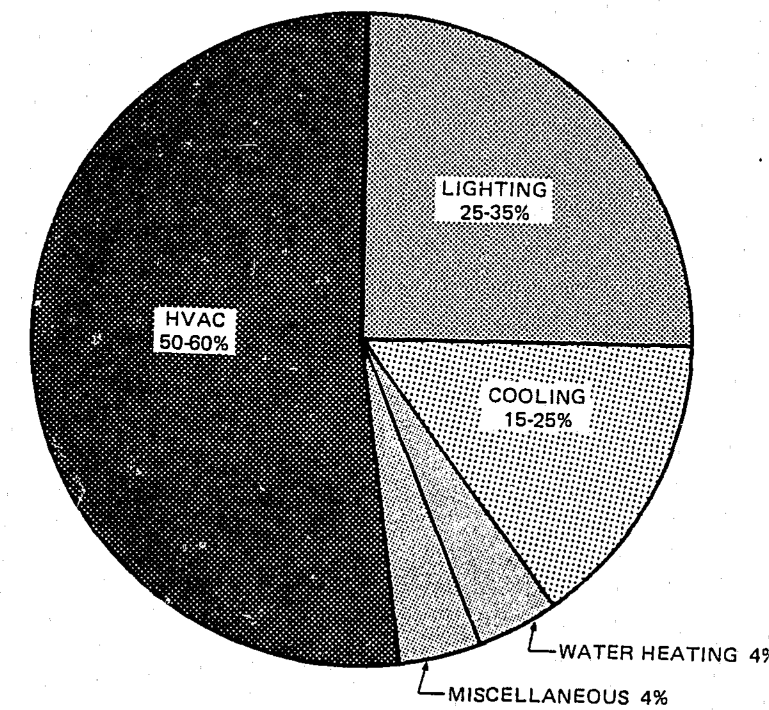


Other states and correctional facilities have reported similar trends. All are faced with the same dilemma - decreasing energy use does not necessarily equate to decreased operating costs. The solution is elusive, but the message is clear - only the minimum amount of energy can be expended to get the job done.

2. How energy is used in correctional facilities. As will be discussed in detail later in the handbook, how energy is used within a facility is a key piece of information used in evaluating where energy may potentially be conserved. Retrofit of the system which consumes the most energy will provide greater cost savings (avoidance) than retrofit of a system which consumes the least. Although the uses of energy within correctional facilities are varied, an example of a typical building energy usage profile is shown at figure 1-4. Heating, ventilation, and air-conditioning (HVAC) accounts for the majority of energy usage in an average building. Electricity used for lighting usually runs a distant second, followed by a myriad of other activities. Since the correctional facility environment

offers many self-sustaining operations, appropriate retrofit options have been included in Chapter V. It is not uncommon to find computers, elevators, escalators, kitchens, laundries, garages, industrial shops, warehouses, barns, and various administrative buildings within the confines of a correctional facility.

Figure 1-4. Energy Use in a Correctional Facility



3. Energy conservation potential in correctional facilities. The potential for energy conservation in correctional facilities is limited only by one's imagination, even in state or local governments which are tight on capital funds. Correctional facilities are large consumers of energy.

Table 1-1 illustrates the point. The state of New Jersey shows a relatively high energy use figure by their corrections facilities. While the other states shown use significantly lower quantities of energy, they still use large amounts to support the corrections department.

Other factors which increase the conservation potential are the manner in which buildings were designed, the decrease in O&M funds and staff, and the minimal application of energy-conserving opportunities. While the application of alternative energy sources to date (solar, wood-burning, photovoltaic cells, etc.) does not itself increase the conservation potential, it does reduce the facility's reliance on conventional fuels.

Energy Conservation Opportunities (ECO's) are covered in Chapter V and will not be specifically addressed here, but are worth mentioning as being one of the many components of a successful energy conservation program.

4. Results achieved in correctional facilities. The specific results achieved to date in various correctional facilities will be mentioned and discussed in appropriate sections of the handbook. However, let it suffice to mention here that the vast majority of the reported results have been positive, with overall energy savings ranging from 10 to 60 percent. In many cases, the Simple Payback Period (SPP) for retrofit options has been less than 1 year. Some institutions have not only conserved energy through their efforts, but also have enhanced the living conditions of the residents by increasing the operating efficiency in HVAC systems. To sum it up, the results achieved to date with the accompanying benefits have outweighed the capital investments and efforts of the facility staff.

For illustration purposes, some achievements are cited below. These are but a few of the examples received from the states during the information-soliciting phase of this program.

a. In the state of Florida, 36 out of 78 correctional facilities reported a decrease from FY 1978 to FY 1979 in total Btu's consumed.

b. An energy conservation study of the Federal Correctional Institution at Butner, North Carolina, resulted in a 21-percent annual energy cost savings, a 24-percent reduction in total annual Btu consumption, a cost-avoidance of $51,000 per year, and an average payback period of 9 months for recommended retrofits.

c. At the Jamesbury, New Jersey, Correctional Facility, approximately $800,000 was invested in major steam line and condensate system replacement, resulting in a reduction from 941,690 to 626,651 Btu per gross square foot (gsf) per year, or 33.5 percent.

Table 1-1. Energy Use in State Facilities

	New Jersey	Massachusetts	Pennsylvania	Minnesota
Colleges				
Btu/Sq. Ft.	168,500	-	133,915	100,000
kWh/Sq. Ft.	13.9	-	10.9	12.2*
Total Btu/Sq. Ft.	329,740	210,000*	260,355	244,520
Human Services				
Btu/Sq. Ft.	295,800	-	340,475	146,000
kWh/Sq. Ft.	8.6	-	6.4	5.9
Total Btu/Sq. Ft.	395,560	395,000	314,715	214,440
Corrections				
Btu/Sq. Ft.	626,500	-	309,960	130,000
kWh/Sq. Ft.	18.6	-	4.9	7.2
Total Btu/Sq. Ft.	842,250	337,000	366,800	213,520

*Reflects lower air conditioning loads during the summer.

d. Under the Tennessee Energy Authority's State Building Energy Management Program, Energy Conservation Opportunities (ECO's) fully implemented as of September 1, 1980, have resulted in a yearly cost-avoidance of $30,718 with only a $631 investment.

e. Montana's Energy Usage Index (Btu/gsf/degree days (DD)) for their correctional institutions has steadily decreased since base year 1973.

This list could be expanded to include many more states. The results show that conservation opportunities can be identified, that positive savings can be achieved, and that past efforts have paid off. Future efforts will hopefully follow a similar trend.

5. Special considerations. The development of an energy conservation program in a correctional facility will present a number of unique considerations for administrators of state and local correctional agencies. Unlike establishing such a program in another public service facility, such as a school or a hospital, there are numerous problems inherent in developing energy conserving measures in an institution where the clientele is obviously less than motivated to cooperate in either its development or maintenance.

Prisons, particularly older facilities constructed prior to 1940, tend to be huge physical complexes with large inmate populations. The San Quentin Prison in California, the Stateville Correctional Center in Illinois, the Jackson State Prison in Michigan and the Ohio Penitentiary in Columbus all have held over 4,000 inmates. Prisons tend to be old; 61 maximum-security prisons still in operation opened before 1900.

With the aforementioned in mind, antiquated facilities, security concerns, clientele which have diverse backgrounds and needs, etc., it is apparent that the development of a comprehensive energy program in the confines of a correctional facility is difficult. However, it is by no means an impossible task. As will be seen in later sections of this handbook, there are many characteristics of correctional institutions which can be utilized to bring about an effective, on-going energy program. For example, many individuals in the inmate population, given the proper motivation, can prove to be highly capable employees in an industry geared toward the manufacturer of energy conservation devices such as solar panels and woodburning fireplaces.

B. Methods for Achieving Energy Savings in Correctional Facilities

Subject to the special considerations already discussed, the methods for achieving energy savings in correctional facilities are no different than those for achieving these savings in any other building complex or facility. The three principal methods are described briefly below and are discussed in more detail in later sections of this handbook.

1. Improved operations and maintenance. This method consists of increased attention to routine day-to-day operational and maintenance matters which involve little or no increase in capital investment. Operational energy savings activities include those which can be affected by "turning off and turning down" systems that waste energy. Basic maintenance functions, such as caulking, repainting, weatherstripping, etc., are energy savers that can easily be worked into the daily maintenance schedule.

2. Retrofitting buildings and energy using systems. An even greater potential savings exists in the retrofitting of existing buildings or energy-using equipment, or both. Retrofitting involves modifying existing buildings and equipment through elimination, or addition of equipment, materials or devices to produce energy savings.

3. Using renewable energy sources. The first two methods for achieving energy savings in correctional institutions, cited above, employ conventional approaches most often used in energy conservation efforts. Presented under this third method are some of the more promising alternative renewable sources of energy. They are increasingly being applied to meet our energy needs in an effort to decrease reliance on imported oil. These alternate sources are solar thermal, wind power, biomass, hydropower, photovoltaics, and cogeneration.

CHAPTER II. PROGRAM DEVELOPMENT AND MANAGEMENT

A commodity as essential and as costly as energy must be controlled in a systematic cost-effective manner. This can best be accomplished through the development of a well planned energy management program.

The key question facility management must answer before launching an energy management program is whether energy cost is of any significance in the correctional facility's budget. If not, there is little incentive for initiation of an energy management program. Since fuel costs currently represent 8 percent of the average correctional facility budget, the answer is probably "yes," and an energy management program should, therefore, be initiated.

A. Program Planning

1. Management commitment. No organized, sustained energy management program can result unless top management makes a full commitment and advertises its commitment. Frequent informal visits to such areas as the boiler room by top facility management personnel checking on progress in these areas will do far more good than a dozen memos. It is human nature; things happen when people know the boss is interested in their work.

2. The energy management team. Energy management in a correctional facility presents a dilemma, especially when initiating the program. Energy management must focus on specific individuals, functions and systems, and at the same time be facility-wide and encompass all activities. The practical approach is to form an energy management team with top representatives from Administration, Engineering and Maintenance, Budget Office and a representative from each of the other main components of the facility. Ideally, the team director is from top management. In effect, the energy management team builds a facility-wide framework within which detailed, day-to-day tasks of energy management take place. The team supports and validates the energy management activity by advertising top management's commitment throughout the facility, and evaluating facility-wide impact of proposed energy-saving ideas.

Naturally the day-to-day tasks of energy management fall on engineering and maintenance personnel. Nevertheless, a full committee is advisable to handle the wide range of considerations for energy management. These include recommending facility-wide policies, plans, and procedures to save energy and reduce costs, developing methods to obtain funding for all phases of the program, as well as acting on specific recommendations made by the Director of Maintenance and Engineering, and suggestions from various members of the facility staff.

3. Goals and objectives. Many organizations begin energy conservation planning by citing the kinds of activities which will be undertaken. It is far more appropriate to begin by formulating realistic energy conservation goals and objectives. It is prudent to establish more modest goals initially that can be met by the persons responsible for them. Once these initial goals have been accomplished, then set progressively higher goals until the maximum energy reductions are achieved. The goal thereafter, of course is to maintain these

reductions. These goals can be expressed in a variety of ways, depending on the nature of the facility, the types of activity housed by the buildings, seasonal fluctuation in load demand, and many other considerations. Energy goals may frequently be modified by nonconservation factors. For instance, energy conservation in a correctional environment requires satisfactory resident and staff relations to optimize overall conservation goals. Without this interrelationship, it becomes very difficult to reach conservation goals.

4. A strategy for success. Once goals are set, alternative strategies for achieving these goals should be considered. The error most often made is to automatically adopt a favorite strategy prior to considering all possibilities. The process of strategy selection is somewhat interwoven with goal-setting, but every effort should be made to keep it separate. Issues of philosophy frequently arise when optimizing goals. For example, the program space in many correctional facilities is utilized after hours and on weekends for activities often extracurricular in nature. This practice utilizes substantial amounts of energy for facilities which would otherwise be shut down or maintained at minimal consumption levels. Assuming that such activities cannot be conducted during regular hours, the administrator is faced with an interesting issue. Before imposing a strategy of curtailing after-hours use of correctional facilities, however, one must estimate the cost savings to be gained from such a strategy in comparison to other available strategies. It should also be recognized that such energy- and cost-savings estimates must be based on a facility's energy utilization after it has been rendered more energy-efficient.

Strategies, as suggested above, can be developed at three levels:

The programmatic - how programs, services, and scheduling of activities take place in the facility,

The operational - how the facility and its supporting systems are run to house and support the correctional activities, and,

The physical plant and its operating system - how the buildings and their mechanical equipment interface with these activities.

The programmatic, in addition to modifying after-hours usage and even altering institutional schedules, could include the introduction of energy conservation curricular materials and courses to promote an awareness of energy conservation by staff and residents.

The operational level could include strategies to improve fleet vehicle management, keeping living units cooler in the winter and warmer in the summer, conducting cleaning and custodial services during the day so that activity buildings can be closed earlier in the evenings, or conducting such services in the morning while buildings are being heated.

The physical plant level, where the greatest payoffs will be found, requires a strategy which is evolutionary in approach. This kind of strategy is necessary so that obvious waste is eliminated prior to moving into more capital-intensive measures and so that familiarity with all alternative modifications can be gained.

Those institutions that have operated the most successful energy-conservation programs have done so by following a carefully planned and coordinated program, moving from the most elementary of conservation steps to levels of increasing sophistication. A successful program must be based on initiating those procedures which require little capital investment, and on efforts to retrain people and reshape attitudes. An energy management program cannot afford to outpace the capabilities of the people who are responsible for, and involved in, its implementation. This could also be said about the entire energy conservation effort but it is particularly the case for the physical plant level in correctional facilities.

The evolutionary strategy has three elements or components: Quick Fix, Retrofit, and Systems Conversion. As noted here each category offers a greater opportunity for consumption reduction than the one that precedes it. Each also involves an increasing rate of capital expenditures:

	Energy Savings	Payback Period
Quick Fix	10-15%	Up to 6 months
Retrofit	10-20%	6 months-5 years
System Conversion	10 %	2 years-15 years
Accumulated:	30-45%	

5. Funding and budgets. Planning is implied throughout every phase of the development of the energy conservation management program and is an especially important component of budgeting. Unless there is a clear understanding of the direction, extent and general functions of the program, the effective allocation of funds will be very difficult. Additional problems may arise from the way the budgeting process is conceptualized. For example, does a specific expenditure enable the program to attain its goals and objectives?

Before discussing various approaches to identifying and attaining goals and objectives, it should be noted that an energy conservation program pays for itself. The manpower and capital invested in maintaining and operating an energy-efficient facility is offset by reduced fuel bills. Thus, the achievement of energy goals is really a long-term investment in the budget of any facility.

Correctional agencies approach their budgeting process in a variety of manners. Traditionally, middle- and lower-level managers simply have been told by those at the top that a stated sum is available for their programs; many lower-level managers have no input into the decision-making process. Sometimes, lower-level managers who are afforded the opportunity to discuss their needs with those at the top are then excluded from the final decision-making process. Such practices inevitably create problems; therefore, new methods of budgeting are emerging.

Many managers do not consider whether monies spent have enabled them to reach their goals. The ability to stipulate energy conservation goals is seldom well-developed. This inability often leads to a less cost-effective distribution of funds to institutional programs. It is almost inevitable unless there is a clear statement of goals that will allow determination as to whether or not funds are being spent effectively. Furthermore, unless such a determination is made, energy-conserving improvements will not be properly focused or will become potentially misdirected.

The development of the energy conservation program must come from the top down. Correctional managers already have a number of serious problems they must cope with daily. Energy conservation per se will be a low priority to most, given these other problems. Only if central office staff emphasizes the importance of this program and supports it with sufficient funding will institutional administrators make it a priority. A possibility would be to provide not only funding but also support staff to assist with the energy surveys and resultant retrofitting activities.

The life of the budget as it relates to energy conservation is also important. Since most budgets are prepared annually, it is difficult to integrate them with a long-range energy plan that spans 5 or 10 years. Experience has demonstrated that long-term projects, such as an in-depth energy conservation program, may fail if the needed funds are not forthcoming. With this in mind, the yearly budgeting practice needs to be made compatible with the long-range fiscal needs of the energy program.

6. Publicity and information

a. Official announcement

Communication and motivation are essential for the successful implementation of the program. Once the program has been developed, it is appropriate to have an official announcement. The following are examples of factors which might be included in this announcement:

(1) The rapidly increasing cost of energy and projected impact unless conservation is achieved;

(2) The potential for energy savings in the first 2 or 3 years of program operation;

(3) Energy-use reductions and energy cost-avoidance can be attained without adversely affecting the quality of inmate life.

The announcement also should discuss some of the general types of energy-conservation measures which will be implemented.

Text of the announcement should be reprinted in whole or part in the institution's newsletter, if one exists. Alternatively, it could be

distributed to employees, or its availability could be made known. A news release should be sent to various area news media. Copies of the basic energy program should be made available upon request.

b. Use of the institutional newsletter

The institutional newsletter, is an excellent vehicle for providing information on the progress of the program and ways in which staff and inmates can help conserve energy.

Examples of energy news items include monthly energy cost and use data, new programs and ideas, staff and inmates who have become involved, energy conservation tips for the facility which can be put into everyday practice, as well as many other items of interest. The newsletter can serve to keep energy conservation on everyone's mind, and to indicate how the program is progressing, who are the people making it work, and what are the program achievements.

c. Local announcements

All personnel should be kept abreast of their own progress where possible. Feedback in the form of local announcements will generate interest in the program as well as positively reward those already involved. Posting update notices in conspicuous locations will help keep energy conservation on everyone's mind and show people the results of their own efforts.

d. Theme and logo

Once the energy management program is moving, it may be desirable to develop an overall theme, catchword, or slogan to symbolize the institutional energy management program.

The theme can be used as a basis for a logo design, or motto, symbolizing the program. A theme and/or logo could be developed through a contest to heighten personnel and inmate interest, perhaps in conjunction with the recreational program.

Once the name and logo are decided upon, they can be put to a variety of promotional purposes; special letterhead for the program's manager, special news release stationery used to announce program achievements and promotional materials including brochures, bulletins, public service advertising posters, etc. The more people who see the name and logo of the program, the more it will be on their mind. The more it is on their mind, the greater the likelihood that they will become interested and motivated.

e. Congratulatory pieces

Staff and inmates making significant contributions to the program should be congratulated in person and at meetings. Giving praise where it is due is important in gaining and maintaining support.

f. Suggestion program

Establish a suggestion program to encourage energy-conserving recommendations. The program should be open to everyone and recognition of worthwhile suggestions should be given. Suggestions implemented, plus some of the more innovative ideas, could be given special coverage through news releases or the newsletter.

g. Inmate interaction

One of the most difficult problems which may be encountered relates to prisoners and their attitudes toward energy conservation and, more particularly, to the prison itself.

In many cases, inmates feel that they are entitled to use as much energy as they want because they are "paying for it." While the techniques mentioned above can help improve such attitudes, they may not be enough. Accordingly, give strong consideration to incorporating as many elements of the program as possible into the regular activities program. The following are a few simple suggestions on how this can be accomplished.

(1) Council or committee

Many facilities have an overall inmate activities council or committee. By working with the leaders of this group, by explaining the importance of energy management and the potential problems which energy wastage may have, chances are it will be possible to gain their cooperation. By having inmate talking to other inmates about energy conservation, it is far more likely that cooperation will be gained. It also would be possible to establish some type of inmate energy conservation committee. The purpose of this committee would be to, among other things, review proposed program options as part of the general facility committee, note areas of waste and call them to the attention of appropriate personnel and to be sure equipment not being used is deenergized. Check the backgrounds of various inmates; an engineer or architect inmate possibly could be of great assistance.

(2) Newsletter

In many cases inmates are responsible for development of the facility newsletter. In such cases they will be the ones responsible for reporting on developments. The more persons involved in reporting on the progress of the program, the more who will want to see it work and lend their cooperation.

(3) Theme and logo

Development of the theme and logo easily can be made part of the activities program. Many inmates have artistic capabilities that can be put to excellent use.

(4) Signs

Chances are that inmates will enjoy getting involved in development of the signs and posters which can help keep energy management in everyone's thoughts by the use of posters displayed in the various departments and by point-of-use labels.

(5) Other activities

It is very feasible that some inmates could be capable of developing data utilized for formation of energy use calculations, month-to-month comparisons, and so on. The more ways in which inmates become meaningfully involved, the more they will become committed to the program and willing to help conserve. Not to be overlooked is the fact that they will derive a sense of contributing to a highly meaningful program. This can help contribute to the inmate's self-respect, a key factor in most rehabilitation programs. In addition, making the energy program part of the activities program also means that activities staff members become involved. This, too, is a very positive factor and one which cannot be discounted.

7. Resident labor

Prison work programs have experienced a number of emphases since they were developed in the early 19th century. The original emphasis was on work as a meaningful daily activity for prisoners with the stress on the reformative potential of hard labor. Early penologists realized that serious physical and emotional disabilities were the inevitable by-product of long-term idleness.

Prisoner reformation and reduction of idleness, however, were hardly the exclusive purposes of prison work; concern for profits permeated practically every prison factory. With the expansion of imprisonment as our dominant penal sanction, profitable work programs took on even greater significance: the self-sufficient prison became practically every warden's goal.

In the past few years prison industry operations around the country have begun to move away from an explicit treatment orientation. This recent transition has probably occurred for two reasons. First, much recent writing and research has seriously discredited the efficacy of prison-based treatment programs; prison industries are simply following the lead of the corrections field in general in abandoning rehabilitative goals. Secondly, treatment-oriented prison work programs have become too expensive to operate. In an era of increasing fiscal stringency, annual state subsidies to offset supervisory and raw material expenses associated with prison-based manufacturing enterprises have become increasingly less acceptable. Operations that have the capacity, at least in principle, to function as self-sufficient entities are once again being expected to do so. Profits have again become a central concern of prison industry administrators.

It would appear that, given the present state of correctional industry programs, the time is ripe for the development of an energy conservation program employing inmate labor in the manufacture/assemblage of energy-saving equipment. The need for providing meaningful activities for prisoners and the urgent need to develop more economical energy sources have arrived almost simultaneously for correctional administrators.

8. Constraints imposed by the correctional environment

The prison setting obviously presents a number of serious problems for the development and implementation of an energy conservation program.

Custody and control are the dominant concerns of the institutional correctional manager. The primary responsibility is to know where prisoners are at all times. Some administrators become preoccupied with accounting for inmates making it difficult to conduct meaningful programs or permit individualized operation.

Another dominant concern of custody personnel is to establish and maintain security procedures including the development of detailed rules and regulations. Movement of prisoners is carefully planned and controlled to insure security. Where custody is overemphasized, communication between staff and inmates breaks down, resulting in inmates only communicating among themselves. All too often limited interaction can result in violence, bringing at least a temporary end to programs such as any organized energy-conservation endeavor.

Earlier in the Introduction, it was stated that a generally unmotivated inmate population would make it difficult to develop a successful energy program. It must be assumed that individuals who have been confined against their will may be less than enthusiastic in supporting energy conservation. Many prisoners will work against the administration in this area by purposely sabotaging any effort to decrease energy use. Such actions as breaking out windows, damaging heating and cooling pipes and simply failing to close windows, all work against the administration's energy program. Knowing this, agency staff must make the energy conservation program a direct part of institutional life, tying in energy-saving achievements with prisoner incentives. Once they understand that their support of the program will bring about a better institutional environment, many prisoners will work with the administration to improve energy utilization and cut back on wasteful energy consumption. Knowing that reduced vandalism will improve their day-to-day living conditions will in turn cause most prisoners to put pressure on their fellow inmates to support the program. Other techniques can also be employed to gain the support of the inmate population. Savings in energy consumption can be channeled into reimbursements either directly to inmates in the form of rebates or indirectly through the purchase of such items as recreational equipment, movies, commissary supplies, etc. The emphasis here is to acknowledge the role of the prisoners in making the program a success by including them in the resultant savings. This is similar to programs developed by private companies where employees are paid either directly through cash incentives or are rewarded via the company's stock program through common stock shares.

Another problem unique to correctional facilities is the limitation of their designs on developing an energy program. Many older facilities are composed of monstrous buildings resembling large warehouses. A number of such facilities have massive five-, six-, and seven-tier cell blocks originally designed to improve control, surveillance and security. These large cell

houses are generally energy-inefficient. In a cell house at the McAlester State Prison, for example, inmates on the bottom tier, to keep warm, were required to wear warm clothes constantly. However, inmates on the top tier were generally in their underwear as the temperature stayed in the mid-80's. Obviously such temperature extremes are not only hard on inmates and staff, but are indicative of an inefficient energy program.

Although large cell houses are not being constructed today, there are still a number of facilities being built with two and three floors of open galleries. Examples of such facilities built since 1960 include state prisons at Jackson in Georgia, Somers in Connecticut, Leesburg in New Jersey, Ionia in Michigan, Moberly in Missouri, and Canon City in Colorado. These facilities are not quite the energy wasters their predecessors were but still are highly inefficient buildings relative to energy consumption.

Most recently constructed institutions have substituted completely separate floors for the multilevel open tiers. This results in smaller, more discrete units offering improved classification options, better security and more noise abatement. A lesser, and not always planned additional improvement, has been a significant increase in energy savings.

B. Energy Conservation Surveys

An energy management program consists of a series of very definite phases normally executed in sequence to assure maximum effectiveness. The initial phases, the selection of the Energy Management Team and the establishment of goals and strategies, have been discussed in earlier sections of this handbook. Following these is the conduct of an energy survey of a facility's building or complex of buildings.

1. Role of the physical survey. The object of this phase of an energy management program is to calculate the total energy use of the facility in question and then to identify the particular zones and features of the facility which account for that energy use. The facility survey thus consists of:

a. An audit of the facility's annual expenditures for fuel, utility services, and related items (maintenance of power and distribution systems, replacement of lights and filters, etc.);

b. A detailed physical examination and measurement of the facility itself, including the shell, distribution systems, and electrical and mechanical equipment;

c. Identifying ECO's;

d. Evaluating and ranking ECO's; and

e. Implementation of ECO's.

2. Use of the energy conservation handbook in surveys. This handbook has been carefully designed to enhance and simplify the work of correctional facility managers and engineers in the analysis and modification of existing

facilities to reduce energy use and costs. The handbook offers a field-tested approach to identifying, analyzing, and recommending action on a wide range of options available to reduce energy use in most existing buildings. The handbook provides a step-by-step methodology for assessing and improving the year-round energy performance of buildings as well as a series of forms and charts designed to assist correctional facility personnel in attaining and maintaining this improved performance.

3. Surveys in correctional facilities. Conducting an energy conservation survey in a correctional institution, particularly a maximum security facility, may prove to be a difficult undertaking. Unlike conducting a similar survey in a factory, office building or even a general hospital, the survey of a prison will present several unique obstacles.

The first such obstacle is presented by the correctional facility itself. As is obvious by now, most such facilities are old and dilapidated, only still in use as a result of increased commitments from the courts and no newer facilities to replace them. Although there may be annual movements to have these buildings closed, it is apparent they will be populated until the prison population decreases or a large building program is established.

Since this situation will continue to persist, it behooves correctional administrators to make the best use of these existing structures. Conducting energy surveys in these facilities will require the Energy Conservation Team (ECT) going into areas of the institution rarely frequented by the staff. These areas will include pipe tunnels and chases subject to minor flooding, rat and insect infestation, electrical short circuits, etc., attics of cell houses which are unlit and inadequately reinforced, and high security areas such as guard towers, which are difficult to even get into.

The second obstacle, although not present in all facilities, but which will be a concern in institutions where the resident population is a constant security issue, is the danger and/or harassment created by prisoners who will confront members of the ECT either physically or, more realistically, verbally. For these reasons it may prove worthwhile to conduct the survey of the facility, particularly the living units, when the inmates are at work, school or some other function. This will enable a thorough review, with a minimum of intervention, of the inmate's cells, rooms, dangerous spaces, and other auxiliary areas. However, this may not be possible with such units as administrative and disciplinary segregation where prisoners are confined on a constant basis. Here inmates may be temporarily reassigned while the survey is being completed or, should they not be a real problem, allow them to remain in their units.

C. Monitoring Results and Follow-Up

Keeping records of energy use is not as difficult as one might think. In fact, many of the states, if not all of them, having already developed and are using some sort of system by which energy consumption figures are passed from the user level to the state level for necessary monitoring purposes. One of the problems that we have encountered in our attempts to acquire energy consumption figures is an apparent lack of communication between the correctional facility manager staff and the office (Energy, Budget, or Other) which pays the bills or otherwise keeps record of the consumption data. For example, during Phase I of this program, the Department of Correction

and the Department of Energy for every state and territory was contacted in writing and requested to supply essential items of information concerning energy use by correctional institutions. The responses varied from no information to more information than asked for. The types of responses also confirmed the aforementioned problem and uncovered others.

Rather than question, or attempt to draw conclusions from, the negative or incomplete responses rendered, we believe that there is advantage to advertising some of the systems or procedures utilized by the states who apparently have their energy consumption and total conservation program under control.

The Illinois Institute of Natural Resources employs the Consolidated Building Energy Reporting System (CBERS) to secure management control of energy use. By means of computerized reports, top-level management can review, on a recurring basis, key energy usage indicators for all included state-owned buildings. The system also lends itself to use by individual Department Directors (Corrections, for example), if they so desire, by coding all buildings. The only apparent flaw in this system is that it is voluntary at this time - not all state agencies/offices are required to participate.

Florida represents an unusual example where the Department of Corrections maintains and monitors energy consumption data for all correctional facilities over 5,000 square feet. The Department of Corrections works directly with the Governor's Energy Office and the Department of General Services in accomplishing this task of monitoring energy consumption data. The new data of energy consumption figures is solicited from the user or correctional facility level through use of a standard form. Constants such as climate zone, square footage, conversion factors (for Btu's) are already on file for each facility. The variables are supplied on a monthly basis. The key to the correctional facilities' capability of providing the information is access to the energy bills.

In New Jersey, a monthly report of fuel usage is submitted to the Bureau of Institutional Support services by each institution. The report undergoes analysis and scrutiny to detect any wide variation or sudden increase of an unexplainable nature. When these fluctuations occur, an investigation is made to determine the reason, and what necessary corrective measures are being taken.

Obviously, the states with numerous correctional facilities have the need for more elaborate means of tracing energy usage. However, energy conservation is important in every state, no matter how many jails, prisons, or detention centers are contained therein. The Illinois and Florida examples happen to come from states with drastically different situations with regard to state correctional facilities. They both have excellent computer systems.

Smaller states with few correctional facilities might only need handwritten records to accomplish the same thing as larger states. Connecticut, with only 10 facilities in a relatively small geographic area, can neatly summarize energy consumption data on a single sheet of paper. Texas represents another extreme, with 254 county jails.

Whatever the case, then, the point of the message is clear. The consumption data must be funneled through the proper levels within the corrections side of the house. The information may very well be presented in different forms at different state levels, but will always convey the correct picture of the energy conservation program.

CHAPTER III. SURVEY METHODOLOGY

A. Overview of Method for Identifying Retrofits

There are numerous engineering and Government manuals that include building retrofit projects for saving energy. The examples provided in those manuals are based on the success of similar projects in prior applications. The method provided here is designed to build on this success by relating the appropriate, proven projects to specific energy use systems that can be easily identified in a given correctional facility.

The method employed parallels that used in a full-scale engineering survey. However, checklists, reference tables, and simple calculations based on the experience of others are substituted for the more complex analysis and measurements entailed in a full-scale engineering effort. The method, of course, cannot provide the precision of an engineering study, but it is not intended to. Its purpose is only to identify sound retrofit projects and provide approximate measures of their relative merits for budgetary planning, not to develop engineering designs and detailed life-cycle costs of the projects themselves. Therefore, the survey method was streamlined and simplified so that it requires a minimum investment of time and resources.

1. Method steps

Step 1 - Collecting energy use data. This step provides the fuel cost data necessary to calculate cost savings in a later step, and also provides an overall sense of priority for retrofit projects. Fuel forms that account for the largest part of the total fuel bill should receive greatest emphasis in planning retrofit projects.

Step 2 - Categorizing buildings. In this step, all of the buildings at a facility are identified in terms of size, and thus by their probable proportion of energy use; buildings are categorized into types; and the climate zone that corresponds to a facility's location is identified.

Step 3 - Identifying retrofit options. In this step, reference checklists link appropriate candidate retrofit options with specific energy systems as a function of building type and the climate zone in which the building is located. In addition, retrofit projects already planned can be easily incorporated.

Step 4 - Evaluating and ranking retrofit projects. In this step the energy and cost savings of individual retrofit projects are calculated, along with their associated investment costs. The options are then ranked in terms of the time it would take for them to pay back their investment cost.

2. Tasks

Florida uses its Life Cycle Energy Evaluation Technique to analyze and evaluate projects with a nonrecurring capital cost of $40,000 or greater. This procedure assists management in its decision-making process for evaluatting and ranking retrofit projects. Although many such projects will not cost as much as $40,000, the procedure can be altered to apply to less expensive ones. By using standard data concerning the building in question, one can theoretically apply several retrofits or combinations of retrofits to maximize cost-effectiveness. By performing the analysis on paper, one can save time and money, as well as better present a case for consideration to higher level decision-making and fund-controlling staff personnel. The following section describes, in sequence, the tasks in each of these steps. For each task, either a sample worksheet, reference checklist, or other tool is provided. When completed, these materials can be combined to provide reports on retrofit options for individual buildings and for an entire group of buildings that make up a correctional facility.

B. Method for Identifying Retrofit Projects

1. Step 1 - Identifying fuel use and costs. Because the overall purpose of this manual is to reduce energy consumption, the first task of this method is to determine the amount of each type of energy being used at a facility and what it costs. All else being equal, the potential savings from retrofit projects will be greatest for those that impact on the energy form consumed in the greatest amounts.

Worksheet 1 (appendix A) provides the data format for this task. Figure 3-1 illustrates this worksheet completed for a selected correctional facility. The worksheet requires data on the amounts and costs of each fuel type used over the past several years. The resultant trends can signal a priority area for retrofit potential. Rapid increases in costs for a particular fuel will generally mean that some energy-saving devices affecting that fuel form will make sense now, even if they did not make sense a few years ago. A search of the building maintenance files could turn up ready-made retrofit options.

The data included in the format of Worksheet 1 are not applied directly in the next few steps. This data collection should be carried out first, however, to build in a sensitivity to the fuel forms that are driving energy costs upward at the facility. Appendix A provides reproducible blank data sheets for all the worksheet tabulation requirements relative to the methodology presented here. The data collected on fuel prices will be used in calculating costs and savings near the end of the retrofit project identification procedure. The total amount of fuel saved (in Btu or kWh) will be needed and obtained as a by-product of the retrofit identification process to tabulate and report facility-wide energy savings.

Worksheet 1 can be completed using data for an entire facility, for groups of buildings, or for individual buildings, depending on the level of metering and records available. Data on individually metered buildings are preferred because they will come closest to identifying the relative amounts of energy consumed by individual pieces of equipment within that building. If data on individual pieces of equipment are actually available, they can be applied later in the procedure when specific candidate retrofit projects are addressed. It is also suggested that the box in Worksheet 1 marked "Number of Btu used per year per square foot" be completed for both a base year selected by the ECT (usually 1975) and the present year. This entry will be the total annual energy used (in Btu) at the facility, divided by the total square footage.

Figure 3-1. Example of Worksheet 1 Completed Using Data from Case Study

WORKSHEET 1. ANNUAL ENERGY USE AND COST

FACILITY/BUILDING NAME: *Prince Georges County Det. Ctr.* CODE: ______ DATE: *October 31, 1980*

LOCATION: *UPPER MARLBORO MARYLAND*

YEAR*	ELECTRICITY			NATURAL GAS		FUEL OIL		COAL		OTHER:	
	MAXIMUM kW DEMAND	1,000 WATT HRS. (kWh) USED	COST ($)	NUMBER OF THERMS USED	COST ($)	NUMBER OF GALLONS USED *#2 oil*	COST ($)	NUMBER OF TONS USED	COST ($)	QUANTITY USED	COST ($)
FY 80	*346.8*	*1,411,068*	*84,664*	—	—	*44,911*	*47,156*	—	—	—	—

INFORMATION NOT AVAILABLE

* *Fiscal Year from July through June*

PRESENT COST OF ENERGY SOURCES ($/UNIT)

ENERGY SOURCE	$/UNIT	CONVERSION X FACTOR* =	MBtu
ELECTRICITY	*.06* /kWh	*293*	*17.58*
NATURAL GAS	— /THERM	—	—
FUEL OIL	*1.05* /GAL	*7.21*	*7.57*
COAL	— /TON	—	—
OTHER:	—	—	—

GROSS SQUARE FEET	*56,000*

YEAR	NUMBER OF Btu USED PER YEAR PER SQUARE FOOT
BASE YEAR 1975	—
PRESENT YEAR: *80*	*420,000*

*CONVERSION FACTORS: THE COMMON UNIT OF ENERGY MEASUREMENT IS THE BRITISH THERMAL UNIT (Btu), WHICH ARE THE UNITS USED LATER IN CALCULATING THE SAVINGS FROM RETROFIT PROJECTS. TO CONVERT ENERGY SOURCES TO Btu AND TO MAKE OTHER ENERGY CONVERSIONS, SEE APPENDIX B.

2. Step 2 - Building Categorization

a. Building size. Because the amount of energy consumed in operating a building is largely dependent on the size of the building, a general priority for work done in identifying retrofits can be obtained by simply making a list of the buildings at a correctional facility, beginning with the largest in terms of square feet, and continuing down to the smallest. If information on the precise square footage is not available, estimates can be used.

Worksheet 2 can be used to enter the ranking of buildings according to size. Figure 3-2 provides an example of worksheet 2 completed for the Prince George's County Detention Center using data from an actual energy audit. This worksheet also includes space for data to be entered from the next task.

b. Building category. Subsequent steps of this method will link specific groups of retrofit options to the types of buildings in which they have been most successful. There are five categories of buildings used:

- Administrative/Office
- Hospital
- Resident and staff housing
- Industrial and warehouse
- Maintenance and service.

One of these categories should be entered opposite each building listed in worksheet 2, choosing the category to which the actual building most closely relates. There are three special types of buildings that deserve mention:

(1) Industrial facilities. The method presented in this handbook treats only building retrofit options, and does not cover the energy consumed in manufacturing operations.

(2) Combination of offices with other structures. In this situation, both building types should be entered in worksheet 2 and the options given later for both categories of buildings should be pursued. However, the lists of options for the two building types will not be mutually exclusive, and should be cross-checked to avoid redundant work.

(3) Buildings with changing functions. Correctional facility plans should be checked to determine whether any of the buildings will be converted from one category to another. If this is the case, enter the new categories in worksheet 2.

A space has also been provided in worksheet 2 for notes pertinent to individual buildings. In this space, notes can be made on unusual hours of operation (more or less than normal) or buildings which are linked by central heating

Figure 3-2. Example of Worksheet 2 Completed Using Data from Case Study

WORKSHEET 2. BUILDINGS IDENTIFIED BY SIZE AND CATEGORY

FACILITY: Prince George's County Detention Center DATE: October 31, 1980

BUILDING NAME, OR NUMBER	APPROXIMATE SQUARE FOOTAGE	BUILDING CATEGORY	NOTES
1. Offices	9,000	Administration	Heated by #2 Fuel Oil
2. Cell Blocks	47,000	Resident Housing	Divided into old and new sections constructed in 1928 and 1976
3.			Hot Water Heating No Outdoor Recreation Area.
4.			Elevators in new section Overcrowded - 551 inmates for
5.			140 cells.
6.			
7.			
8.			
9.			
10.			
11.			
12.			

or cooling systems. Reminders can also be entered about retrofit projects already undertaken or planned. In addition, if a building will be demolished or abandoned within 5 years, that information should be entered under "Notes."

c. Climate zones. Because weather conditions have a large impact on the amount of energy consumed by individual energy-use systems, the value of many retrofit options varies with the area of the country. Later, reference checklists will match specific groups of retrofit options with specific climate zones within the country to reflect this variation in the value of retrofit projects with weather.

Figure 3-3, the map on the next page, divides the country into seven climate zones. The zone corresponding to the facility being addressed should be selected from this map. The zones of the map correspond to heating degree-days (HDD), a measure of the amount of cold weather experienced on the average in an area. Also shown are the corresponding cooling degree days (CDD). Within the zones shown on the map, there are areas of weather anomalies, when the heating and cooling degree-days shown do not correspond to those for the entire zone. A phone call to the nearest office of the National Weather Service, a local utility, or other fuel distributor, can verify the heating and cooling degree-day figures given for the zone on the map where the facility is located. If they do not match, the actual heating and cooling degree-days will correspond to another zone, and that zone should be used as the reference in later steps.

3. Step 3 - Retrofit option identification. The retrofit options that will have the best payoff vary from one climate zone to another because the systems consuming the most energy vary with climate zones. Obviously, changes to heating systems will pay off in Michigan more than they will in Florida.

The reference checklists, shown as figures 3-4, 3-5, 3-6, and 3-7, have been prepared to correspond to the weather conditions dictated by the climate zones for the nation. The retrofit choice option characteristics of the seven climate zones fall into four basic groups, and therefore, each of the seven climate zones has been assigned to one of the checklists. Only one of the four is needed to examine retrofit options for a particular facility. The variation among the checklists reflects the climatic dependence of retrofit options. Options that probably would not pay off in 5 years in a particular zone are excluded from the checklists for that zone.

The checklists group retrofit options by energy-using systems, such as heating and ventilation, with the highest probable energy-use categories listed at the top left of the figure. The descending order of the energy systems from top to bottom down the left side of the figures reflects the probable relative energy use for that system in the climate zone addressed by each checklist. In addition, in the later descriptions of the options themselves, the estimates provided for the potential energy savings will vary among zones for options that have been included in the checklists for more than one zone.

The figures use the same building categories as were used to classify building types in Worksheet 2. These building categories are repeated on the upper right side of the figures. The retrofit options that should be considered for each building category are identified with a dot (•). Each

Figure 3-3. United States Climate Zones

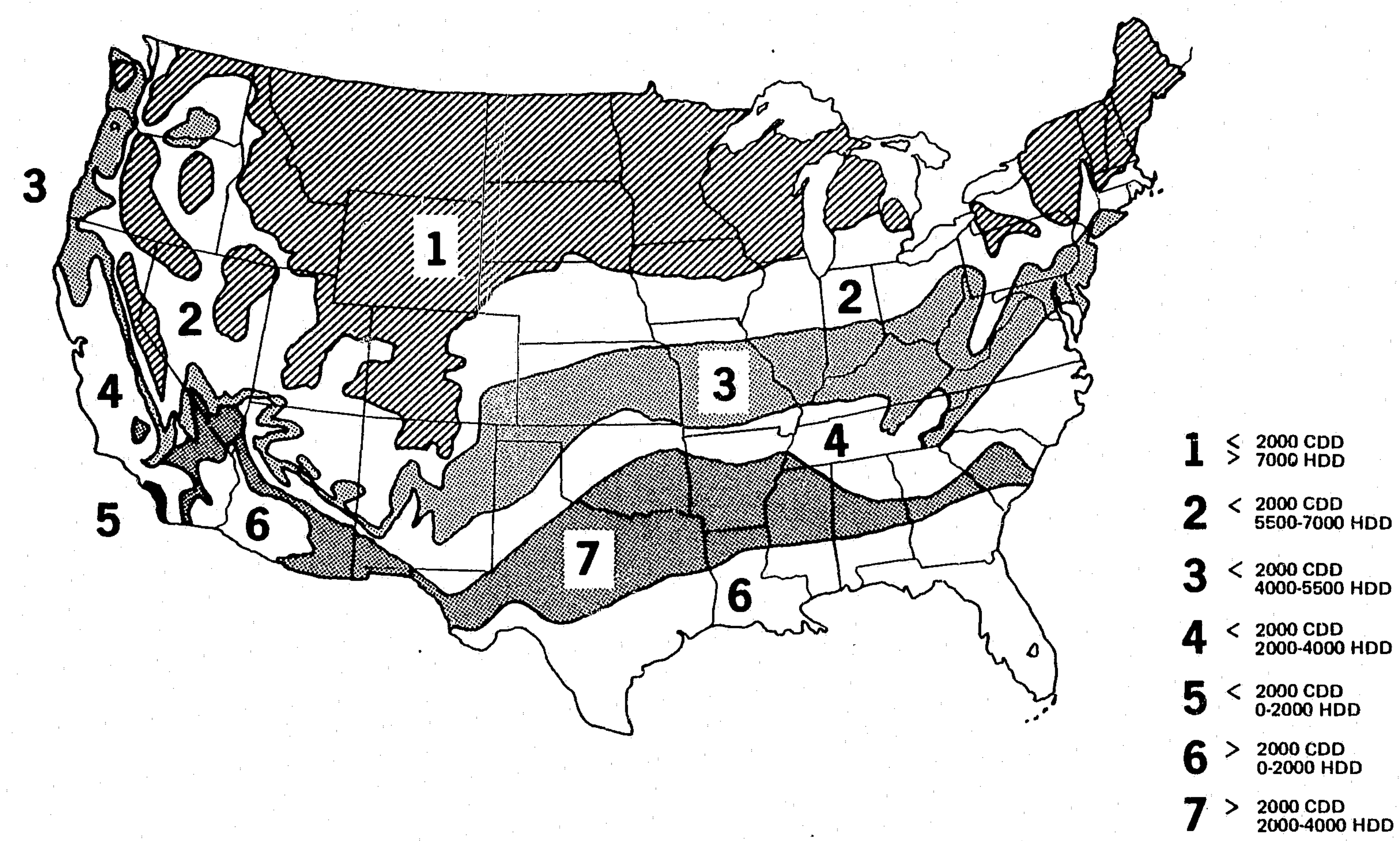


Figure 3-4. Climate Zone 1 Retrofit Options

	ZONE 1 RETROFIT OPTION NUMBERS AND TITLES		POTENTIAL OPTIONS BY BUILDING TYPE: Office	Hospital	Staff & Resident Housing	Industrial & Warehouse	Maintenance & Service
Heating and Ventilation	H-1	Insulate Hot Bare Heating Pipes	●	●	●	●	●
	H-2	Insulate Steam Lines	●	●	●	●	●
	H-3	Return Steam Condensate to Boiler	●	●	●	●	●
	H-4	Install and/or Replace Steam Traps	●	●	●	●	●
	H-5	Preheat Combustion Air	●	●		●	
	H-6	Replace Worn Boiler Controls	●	●	●	●	●
	H-7	Install Boiler Oxygen Analyzing Equipment	●	●		●	
	H-8	Preheat Boiler Feed Water	●	●		●	
	V-1	Close Off Unoccupied Areas	●	●	●	●	●
	V-2	Shut Down Air Distribution System	●	●		●	●
	V-3	Shut Down Exhaust Systems	●	●		●	●
	V-4	Install Automatic Thermostats	●	●	●	●	●
	V-5	Reduce Air Volume	●	●		●	
	V-6	Install Energy-Recovery Equipment		●		●	
Cooling	C-1	Install Time Clocks for Air Conditioners	●	●			●
	C-2	Replace Inefficient Air Conditioners	●	●			●
	C-3	Install Temperature Controller and Sensor	●	●	●		
	C-4	Install Economizer Cycle	●	●	●		
	C-5	Control Solar Heat Gain					
Lighting	L-1	Remove Lamps or Fixtures	●	●	●	●	●
	L-2	Use Energy-Conserving Fluorescent Lamps	●	●	●	●	●
	L-3	Control Exterior Lighting	●	●	●	●	●
	L-4	Use More Efficient Lighting Sources	●	●		●	●
	L-5	Install Switching	●	●		●	●
Water Heating	W-1	Install Water Flow Restrictors	●	●	●		
	W-2	Insulate Domestic Hot Water Tank	●	●	●	●	●
	W-3	Install Decentralized Water Heating	●	●	●	●	●
	W-4	Use Waste Heat for Water Heating		●		●	
Architectural	A-1	Install Caulking	●	●	●	●	●
	A-2	Install Weatherstripping	●	●	●	●	●
	A-3.1	Install Wall Insulation	●	●	●		
	A-3.2	Install Roof Insulation	●	●	●	●	●
	A-4	Install Storm Windows	●	●	●		
	A-5	Install Thermal Barriers	●	●	●		
	A-6	Install Loading Dock Door Seals	●	●		●	
	A-7	Install Vestibules	●	●	●		
Misc.	M-1	Control Elevator Operation	●	●	●		
	M-2	Correct Poor Power Factor	●	●		●	●

Figure 3-5. Climate Zone 2 Retrofit Options

	ZONE 2 RETROFIT OPTION NUMBERS AND TITLES		POTENTIAL OPTIONS BY BUILDING TYPE: Office	Hospital	Staff & Resident Housing	Industrial & Warehouse	Maintenance & Service
Heating and Ventilation	H-1	Insulate Hot Bare Heating Pipes	●	●	●	●	●
	H-2	Insulate Steam Lines	●	●	●	●	●
	H-3	Return Steam Condensate to Boiler	●	●	●	●	●
	H-4	Install and/or Replace Steam Traps	●	●	●	●	●
	H-5	Preheat Combustion Air	●	●		●	
	H-6	Replace Worn Boiler Controls	●	●	●	●	●
	H-7	Install Boiler Oxygen Analyzing Equipment	●	●		●	
	H-8	Preheat Boiler Feed Water	●	●		●	
	V-1	Close Off Unoccupied Areas	●	●	●	●	●
	V-2	Shut Down Air Distribution System	●	●		●	●
	V-3	Shut Down Exhaust Systems	●	●		●	●
	V-4	Install Automatic Thermostats	●	●	●	●	●
	V-5	Reduce Air Volume	●	●		●	
	V-6	Install Energy-Recovery Equipment		●		●	
Cooling	C-1	Install Time Clocks for Air Conditioners	●	●			●
	C-2	Replace Inefficient Air Conditioners	●	●	●		●
	C-3	Install Temperature Controller and Sensor	●	●	●		
	C-4	Install Economizer Cycle	●	●	●		
	C-5	Control Solar Heat Gain	●	●	●		
Lighting	L-1	Remove Lamps or Fixtures	●	●	●	●	●
	L-2	Use Energy-Conserving Fluorescent Lamps	●	●	●	●	●
	L-3	Control Exterior Lighting	●	●	●	●	●
	L-4	Use More Efficient Lighting Sources	●	●		●	●
	L-5	Install Switching	●	●		●	●
Water Heating	W-1	Install Water Flow Restrictors	●	●	●		
	W-2	Insulate Domestic Hot Water Tank	●	●	●	●	●
	W-3	Install Decentralized Water Heating	●	●	●	●	●
	W-4	Use Waste Heat for Water Heating		●		●	
Architectural	A-1	Install Caulking	●	●	●	●	●
	A-2	Install Weatherstripping	●	●	●	●	●
	A-3.1	Install Wall Insulation					
	A-3.2	Install Roof Insulation	●	●	●		
	A-4	Install Storm Windows	●	●	●		
	A-5	Install Thermal Barriers	●	●	●		
	A-6	Install Loading Dock Door Seals		●		●	
	A-7	Install Vestibules	●	●	●		
Misc.	M-1	Control Elevator Operation	●	●	●		
	M-2	Correct Poor Power Factor	●	●		●	●

Figure 3-6. Climate Zones 3 & 4 Retrofit Options

	ZONES 3 AND 4 RETROFIT OPTION NUMBERS AND TITLES		POTENTIAL OPTIONS BY BUILDING TYPE				
			Office	Hospital	Staff & Resident Housing	Industrial & Warehouse	Maintenance & Service
Heating and Ventilation	H-1	Insulate Hot Bare Heating Pipes	●	●	●	●	●
	H-2	Insulate Steam Lines	●	●	●	●	●
	H-3	Return Steam Condensate to Boiler	●	●	●	●	●
	H-4	Install and/or Replace Steam Traps	●	●	●	●	●
	H-5	Preheat Combustion Air	●	●		●	
	H-6	Replace Worn Boiler Controls	●	●	●	●	●
	H-7	Install Boiler Oxygen Analyzing Equipment	●	●		●	
	H-8	Preheat Boiler Feed Water	●	●		●	
	V-1	Close Off Unoccupied Areas	●	●	●	●	●
	V-2	Shut Down Air Distribution System	●	●		●	●
	V-3	Shut Down Exhaust Systems	●	●		●	●
	V-4	Install Automatic Thermostats	●	●	●	●	●
	V-5	Reduce Air Volume	●	●		●	
	V-6	Install Energy-Recovery Equipment		●		●	
Cooling	C-1	Install Time Clocks for Air Conditioners	●	●			●
	C-2	Replace Inefficient Air Conditioners	●	●	●		●
	C-3	Install Temperature Controller and Sensor	●	●	●		
	C-4	Install Economizer Cycle	●	●	●		
	C-5	Control Solar Heat Gain	●	●	●		
Lighting	L-1	Remove Lamps or Fixtures	●	●	●	●	●
	L-2	Use Energy-Conserving Fluorescent Lamps	●	●	●	●	●
	L-3	Control Exterior Lighting	●	●	●	●	●
	L-4	Use More Efficient Lighting Sources	●	●		●	●
	L-5	Install Switching	●	●		●	●
Water Heating	W-1	Install Water Flow Restrictors	●	●	●		
	W-2	Insulate Domestic Hot Water Tank	●	●	●	●	●
	W-3	Install Decentralized Water Heating	●	●	●	●	●
	W-4	Use Waste Heat for Water Heating		●		●	
Architectural	A-1	Install Caulking	●	●	●	●	●
	A-2	Install Weatherstripping	●	●	●	●	●
	A-3.1	Install Wall Insulation					
	A-3.2	Install Roof Insulation			●		
	A-4	Install Storm Windows					
	A-5	Install Thermal Barriers					
	A-6	Install Loading Dock Door Seals		●		●	
	A-7	Install Vestibules	●	●	●		
Misc.	M-1	Control Elevator Operation	●	●	●		
	M-2	Correct Poor Power Factor	●	●		●	●

Figure 3-7. Climate Zones 5, 6, & 7 Retrofit Options

	ZONES 5,6 AND 7 RETROFIT OPTION NUMBERS AND TITLES		POTENTIAL OPTIONS BY BUILDING TYPE				
			Office	Hospital	Staff & Resident Housing	Industrial & Warehouse	Maintenance & Service
Heating and Ventilation	H-1	Insulate Hot Bare Heating Pipes	●	●	●	●	●
	H-2	Insulate Steam Lines	●	●	●	●	●
	H-3	Return Steam Condensate to Boiler	●	●	●	●	●
	H-4	Install and/or Replace Steam Traps	●	●	●	●	●
	H-5	Preheat Combustion Air	●	●		●	
	H-6	Replace Worn Boiler Controls	●	●	●	●	●
	H-7	Install Boiler Oxygen Analyzing Equipment	●	●		●	
	H-8	Preheat Boiler Feed Water	●	●		●	
	V-1	Close Off Unoccupied Areas	●	●	●	●	●
	V-2	Shut Down Air Distribution System	●	●		●	●
	V-3	Shut Down Exhaust Systems	●	●		●	●
	V-4	Install Automatic Thermostats	●	●	●	●	●
	V-5	Reduce Air Volume	●	●		●	
	V-6	Install Energy-Recovery Equipment		●		●	
Cooling	C-1	Install Time Clocks for Air Conditioners	●	●			●
	C-2	Replace Inefficient Air Conditioners	●	●	●		●
	C-3	Install Temperature Controller and Sensor	●	●	●		
	C-4	Install Economizer Cycle	●	●	●		
	C-5	Control Solar Heat Gain	●	●	●		
Lighting	L-1	Remove Lamps or Fixtures	●	●	●	●	●
	L-2	Use Energy-Conserving Fluorescent Lamps	●	●	●	●	●
	L-3	Control Exterior Lighting	●	●	●	●	●
	L-4	Use More Efficient Lighting Sources	●	●		●	●
	L-5	Install Switching	●	●		●	●
Water Heating	W-1	Install Water Flow Restrictors	●	●	●		
	W-2	Insulate Domestic Hot Water Tank	●	●	●	●	●
	W-3	Install Decentralized Water Heating	●	●	●	●	●
	W-4	Use Waste Heat for Water Heating		●		●	
Architectural	A-1	Install Caulking	●	●	●	●	●
	A-2	Install Weatherstripping	●	●	●	●	●
	A-3.1	Install Wall Insulation					
	A-3.2	Install Roof Insulation					
	A-4	Install Storm Windows					
	A-5	Install Thermal Barriers					
	A-6	Install Loading Dock Door Seals					
	A-7	Install Vestibules					
Misc.	M-1	Control Elevator Operation	●	●	●		
	M-2	Correct Poor Power Factor	●	●		●	●

option has a number corresponding to its sequence in the heating, ventilating, cooling, lighting, water heating and miscellaneous sections. A short introduction to each section provides general information about the energy use systems described within the section. The option descriptions themselves explain the procedure for evaluating this particular option in a particular building. Included in each option description is a space for notes and the calculations needed for evaluation.

The procedure can be summarized as follows:

- o Zone checklists serve as a source for retrofit options to be studied for each building.
- o Option sections (e.g., Heating) have short descriptions and explain how to evaluate each option, and provide a worksheet for the necessary notes and calculations.

In addition to those retrofit options identified in chapter V, other suggested energy conservation options have been incorporated into chapter VI. These opportunities include options not normally providing a SPP of less than 5 years except in special cases, and options which are inherently difficult to quantify. These retrofit opportunities do not include the information required to calculate the energy savings and simple payback period (SPP). Instead, each option presents a brief description of the potential retrofit application for saving energy and any techniques required for implementing the option.

Also, a special chapter VIII has been devoted specifically to presenting some techniques other than retrofit through which energy may be saved in prisons and jails.

4. Step 4 - Evaluation and ranking of retrofit options. In each option description, planning factors are supplied for estimating:

- o Energy savings (in millions of Btu/yr or kWh/yr)
- o Energy cost-savings/year (in dollars)
- o Capital cost of the retrofit.

Since it is these data that provide the basis for comparing retrofit projects, care should be taken to carefully follow the directions for the various calculations. Worksheet 3 has been provided to help organize the material necessary to complete the calculations associated with each of the options studied. Figure 3-8 provides an example of worksheet 3 completed using data from a case study.

For retrofit projects that have been previously planned for a building, a worksheet can be prepared that also includes this same information plus a brief description of the project itself.

Figure 3-8. Example of Worksheet 3 Completed Using Data From Case Study

WORKSHEET 3. CALCULATIONS

Facility: FCI EL RENO Date: NOV 7

Building Identification: GEN. SERVICES Prepared by: J. JONES

Option No.: H-4 and Title: REPAIR STEAM TRAPS

Work Description: IDENTIFY BAD STEAM TRAPS USING ULTRASONIC DEVICE. REPAIR STUCK VALVE TO PREVENT STEAM LOSS.

ORIFICE SIZE = $\frac{1}{8}$ INCH STEAM PRESSURE = 125 PSIG

NO. OF BAD TRAPS = 15

Energy Savings:

= NO. OF LEAKING TRAPS X STEAM LEAK LOSSES X 970 BTU/LB X HOURS OF OPERATION/YEAR ÷ EFFICIENCY FACTOR (TABLE B-3)

= 15 TRAPS X 85 LBS/HR. X 970 BTU/LB. X 2080 ÷ 0.8

= 3216 X MBTU/YR

Cost Savings:

= ENERGY SAVINGS X COST/10^6 BTU

= (3216 X 10^6 BTU/YR) X \$1.58/10^6 BTU

= \$5081/YR

Capital Costs:

= 15 TRAPS X \$100 EACH TO REPAIR

= \$1500

Simple Payback Period:

$\frac{\text{Capital Cost}}{\text{Cost Savings}} = \frac{\$1500}{5081}$

= 0.3 YR

a. Calculation of simple payback period (SPP). For all the retrofit projects, those from this handbook plus those already planned for a correctional facility, the simple payback period (SPP) should be calculated as an initial step in comparing the options. This can be accomplished with the information and instructions for cost calculations that accompany each individual option description. The SPP determines the time period it will take a project to pay for itself.

$$\text{SPP (years)} = \frac{\text{Total capital cost of retrofit project}}{\text{Net dollar savings per year}}$$

b. Retrofit options. The option descriptions in this handbook call for the calculation of SPP as individual options are examined. Once all the options for an entire correctional facility have been examined, the data for comparing them can be entered on worksheet 4 as shown in the example in figure 3-9. The priority of retrofit projects is based on SPP. Where two or more options have the same SPP, the highest priority should be given to those that maximize the ratio of Btu saved per year/retrofit project investment cost. Reproducible blanks for worksheets 3 and 4 are available in appendix A.

All projects which are subsequently selected from the worksheet 4 list for actual engineering design and funding should have a life-cycle cost analysis done, based on the actual engineering design.

C. Energy Survey Reports

For ease in writing a concise report on each correctional facility surveyed, a simple format is provided here. Three main sections are recommended:

- o Introduction and Overview of Survey
- o Summary Worksheets of Facility Energy Data and Survey Results
- o Analyses/Calculations of Retrofit Options.

Each of these sections is further defined below.

An explanation of how to complete the Summary Worksheets has been given in the preceding sections, and blank reproducible copies of these worksheets are provided in appendix A.

There is a need to assure that the information making up the survey report is uniform, easily understandable and readily assimilated into an overall agency program. The following format provides an easy method to meet these objectives.

1. Introduction and overview of survey

a. Introduction. A narrative, including facility and building names and locations, date of survey, sources of information, personnel responsible for survey report, manhours required to complete survey, etc.

b. Overview of Retrofit Survey. A narrative description of buildings, including equipment used, fuel sources, and building type, structure and design.

Figure 3-9. Example of Worksheet 4 Completed Using Data from Case Study

WORKSHEET 4. RETROFIT OPTION COMPARISONS

Facility: FCI - BUTNER, North Carolina Date: SEPTEMBER 13, 1978

Building	Option Number	Energy Savings		Energy Cost Savings ($/Year)	Capital Cost ($)	SPP (Years)
		Units / Year	MBtu / Year			
1, 4, 15, 19 thru 25	V-5	723,000 kWh/yr	2,170	14471	7500	.5
1, 6, 10, 11, 13, 14, 15, 16	V-2,3	1,055,000 kWh/yr	5,739	20 700	16,400	.8
1 thru 15	V-4	57,500 gal/yr	2,706	7,371	9,240	1.3
ALL	L-1	76,545 kWh/yr	261	1,532	491	.3
1 thru 16	C-1	301,841 kWh/yr	1,030	6,038	1,650	.3
ALL	L-3	25,469 kWh/yr	87	509	565	1.1
ALL	L-2	3133 kWh/yr	11	62	426	6.9

2. Summary tables of facility energy data and survey results

a. Worksheet 1 - Annual energy use and cost. An explanation of this worksheet has already appeared in step 1 of paragraph B. The conversion factors in appendix B will lend assistance in completing this worksheet.

b. Worksheet 2 - Buildings identified by size and category. An explanation of this worksheet was also given in a previous section of this chapter.

c. Worksheet 4 - Retrofit option comparisons. An explanation of this worksheet appears on a previous page. This worksheet will be completed after all appropriate retrofit options have been considered. Be sure to include any project previously studied and/or for which funds are currently requested.

3. Analyses/calculations of retrofit options. In order to assure that all applicable options have been considered, it may be advantageous to reproduce the appropriate climate zone checklist (figure 3-4, 3-5, 3-6, or 3-7). This checklist may be used as a reference and/or included in the report preceding this section. All options should be treated individually. For those options deemed applicable, the completed pages of worksheet 3 should be included. These will be provided as backup material and provide detailed calculations for:

- Energy savings
- Cost savings
- Capital cost
- Simple payback period.

HANDBOOK FOR ENERGY CONSERVATION IN CORRECTIONAL FACILITIES

PART TWO – ENGINEERING ANALYSIS AND RETROFIT OPTIONS

CHAPTER IV. ESTIMATING ENERGY USE IN BUILDINGS

A. Energy Use Terms and Conversion Factors

The glossary at appendix B is a listing of commonly used energy terms which appear in the handbook. It is recommended that the user of this handbook refer to the glossary if any questions arise concerning definitions of any terms.

Energy units in this handbook are expressed in engineering notation. Thus, 1 million Btu is expressed as 1×10^6 Btu, while 1 thousand Btu is expressed as 1×10^3 Btu. Another common notation is the metric system; thousand is expressed by "k", and million by "M". In calculating energy costs and savings, the notations MBtu (1×10^6 Btu) and kWh (1×10^3 watt-hours) are used in this handbook.

While using the handbook, it will occasionally be necessary to convert raw energy units to the common unit of energy measurement, the British thermal unit (Btu). Conversion factors for all energy units used in this handbook are contained in table B-1, appendix B.

B. System Efficiencies

The efficiency of any system is less than 100 percent. The energy losses, for the purpose of this handbook, can be divided into losses that occur external to the building, mostly due to distribution, and losses within the building boundary, due to mechanical or thermal inefficiencies. Table B-3 of appendix B presents typical external and internal building energy system efficiency factors. These factors will be used to estimate building energy use.

Regarding internal inefficiencies, we note that all systems within a building operate at different efficiencies; one of the intents of this handbook is to aid users in conserving energy by selecting the most efficient energy-using system. These internal system inefficiencies increase energy consumption above the theoretical levels, and must be accounted for when estimating energy use and energy savings. Exceptions to this rule are mechanical refrigeration systems and heat pumps, which usually can "transport" heat energy faster than energy must be supplied to power the "transportation system", representing a theoretical efficiency greater than 100 percent. This efficiency is called the Coefficient of Performance (COP). The Coefficient of Performance is always greater than 1. Those COP's that apply to the options presented in this handbook are contained in table B-3 in addition to the efficiency factors for internal systems.

The total system efficiency is given by the product of all the external and internal efficiencies (there may be several internal efficiency losses, depending on the total system design). This procedure is best illustrated by example:

Problem: Calculate the total system efficiency of a 6-horsepower electric motor attached to a pump. Assume that electrical generation is by utility.

Solution: The product of the external and internal efficiency factors equals the total system efficiency. From table B-3, one can find the applicable factors:

	Efficiency Factor
External System	
Electrical Generation (Utility)	0.30
Internal System	
Large Electric Motor (over 5 horsepower)	0.90
Pump	0.70

Total system efficiency = 0.30 x 0.90 x 0.70 = 0.189 or 18.9 percent.

This is equivalent to saying that 1/0.189 or 5.39 units of raw source energy must be consumed to produce 1 unit of mechanical energy from the pump. Selection of the most energy-efficient system therefore is very important when attempting to maximize total system efficiency.

C. Determining Building Energy Use

To complete the retrofit option evaluation presented in chapter V, it is necessary to determine the present energy use of the existing buildings. The easiest way to obtain this information is from utility company billings and fuel oil billings. However, obtaining this information is not always that simple. In some cases energy bills are sent directly to the State or county comptroller's office and are not readily available at individual locations. There are also many instances where single meters are used to serve several buildings so that energy use information is not available for any individual building.

Unfortunately, there are no methods to obtain the exact energy use in buildings other than by metering the individual buildings. However, there are methods that can be used for estimating purposes. These methods are presented in this section followed by a fully worked example in determining building energy use.

1. Heating energy use. The energy used in a building for heating depends on the climate zone location, the type of building, and the type of heating system installed. The five major building categories at correctional facilities are:

a. Administration/Office

b. Hospital

c. Staff and Resident Housing

d. Industrial and Warehouse

e. Maintenance and Service

To estimate the heating energy used, by building category, determine the heating degree-days for the location and the area of the building in square

feet. Then use the factor provided in table 4-1 and multiply to obtain the estimated heating energy use in Btu's per year. Note, however, that the factors given in table 4-1, although they allow for typical heating system inefficencies, should not be used if more accurate data is available. This method of determining heating energy use is illustrated in the example problem at the end of the chapter.

Table 4-1. Building Energy Use Estimating Factors*

	Heating Btu/HDD/ft^2	Cooling Btu/CDD/ft^2	Lighting Watts/ft^2
Administration	20	20	2-4
Hospital	35	35	2-4
Staff and Resident Housing	15	15	.25-1.0
Industrial and Warehouse	10-30	10-30	1-3
Maintenance and Service	10-30	10-30	1-3

*Electrical energy use by appliances and other equipment may be estimated by using the procedures outlined in paragraph C5. Table 4-2 gives some annual energy use estimates for selected appliances.

2. Cooling. Compressor energy use in kilowatt-hours per year can be estimated by multiplying the horsepower of the compressor by the total full-load hours and by the conversion factor 0.746 kW/hp. For the climate zones identified in figure 3-3, use the following equivalent full-load hours:

a. Zone 1 — 800 hrs./yr.
b. Zone 2 — 1,100 hrs./yr.
c. Zone 3, 4 — 1,400 hrs./yr.
d. Zone 5, 6, 7 — 1,700 hrs./yr.

For example, for a cooling system of 5 horsepower located in climate zone 2, the energy used for cooling would be:

5 hp x 1,100 hours/year x 0.746 kW/hp = 4,103 kWh/year

If the horsepower rating is unobtainable, then another method for estimating cooling energy use can be employed. Determine the annual cooling degree-days for the building location, and the area of the building in square feet, as was done for estimating heating energy use. Choose the factor from the second column of table 4-1 that corresponds to the applicable building category. The product of this factor, the cooling degree-days, and the building's square footage yields the estimated annual cooling energy use in Btu/year.

3. Ventilation. In larger heating and cooling systems, fans are used to distribute air throughout the building. The energy used by the ventilating system, in kilowatt-hours per year, can be estimated by multiplying the horsepower of the fan by 0.746 and the number of hours per year that the fan operates.

4. Lighting. To estimate the energy used for lighting, it is necessary to count or estimate the total wattage of the lighting system in each building. Multiplying the wattage by the number of hours of operation of the lighting system per year will produce the annual watt-hour usage of the system.

5. Appliances. The energy use of appliances typically found in correctional facilities buildings is given in table 4-2. The annual energy use of any electricity-consuming piece of equipment can be estimated by multiplying the number of hours of annual usage by the wattage of the piece of equipment. If these two factors are available and accurate, then use this product instead of table 4-2 for the energy use estimate.

Table 4-2. Energy Use of Major Appliances*

	Annual Energy Use	
Appliance	Electricity (kWh)	Gas (Cubic Feet)
Refrigerator	1,680	
Dishwasher	360	
Clothes Washer	120	
Clothes Dryer	1,200	6,000
Range/Oven	1,200	8,400
Water Heater	7,200	36,000

*Jones, J. W., Hendrix, B. J. Residential Energy Requirements and Opportunities for Energy Conservation; ASHRAE Symposium Paper No. DA76-4, November 6, 1975.

D. Example Problems

1. Individually metered buildings. If the building has its own metering then the building energy use can be obtained directly from the utility bills.

The energy units that are read off the bill can be converted to Btu's using the conversion factors in table B-1, appendix B.

Examples:

a. Utility bills show 10,000 kWh were used each month for one year, therefore, the energy use for electricity is:

10,000 kWh/month x 12 months/year x 3,413 Btu/kWh =
409 x 10^6 or 409 MBtu/year

b. The amount of natural gas used was 100,000 cubic feet per month, therefore, the energy use for natural gas is:

100,000 ft^3/month x 12 months/year x 1030 Btu/ft^3 natural gas =
1236 x 10^6 Btu/year or 1236 MBtu/year

If gas and electricity are the only energy sources used, then the total building energy use is:

409 MBtu/year + 1236 MBtu/year = 1645 MBtu/year

2. Centrally metered buildings. Many correctional facilities use a central meter for several types of buildings having different functions. The following example presents a method of proportioning the total energy to each building. It employs some of the methods for estimating energy use that were previously discussed in this chapter.

Example: The following buildings are centrally metered for gas and electricity. The watts/ft^2 and annual hours estimates have been given for the purposes of this example. These quantities can be determined for any building by applying the procedures covered earlier in this chapter.

Building A

Function: Housing

Area: 10,000 ft^2

Electric Use: Lighting - 1.0 watt/ft^2 (from table 4-1); 3,000 hours/year (estimate)

Appliances - 1.0 watt/ft^2 (estimate); 3,00 hours/year (estimate)

Gas Use: Heating, Efficiency Factor = 0.80; 15 Btu/HDD/ft^2 (from table 4-1)

Building B

Function: Administration

Area: 2,000 ft^2

Electric Use: Lighting - 3 $watts/ft^2$ (from table 4-1); 2,500 hours/year (estimate)

Power - 0.5 $watts/ft^2$ (estimate); 2,500 hours/year (estimate)

Cooling - Coefficient of Performance = 2.5; 20 $Btu/CDD/ft^2$ (from table 4-1)

Gas Use: Heating, Efficiency Factor = 0.80; 15 $Btu/HDD/ft^2$ (from table 4-1)

Building C

Function: Maintenance

Area: 5,000 ft^2

Electric Use: Lighting - 1.0 $watt/ft^2$ (from table 4-1); 1,000 hours/year (estimate)

Heating - 10 $Btu/HDD/ft^2$ (from table 4-1)

Gas Use: None

Building D

Function: Industrial

Area: 10,000 ft^2

Electric Use: Lighting - 2 $watts/ft^2$ (from table 4-1); 3,000 hours/year

Power - 2 $watts/ft^2$ (estimate); 3,000 hours/year

Gas Use: Heating, Efficiency Factor = 0.80

Annual Utility Use: Electricity - 200,000 kWh/year;

Gas - 2,000,000 ft^3/year

The preceding information represents the minimum necessary to proceed with this problem. Some of the items have been taken from table 4-1, or were estimated. The $watts/ft^2$ estimates can be made based on the wattage of the particular piece of equipment and the square footage of the area served. The given efficiency factor and coefficient of performance can be selected from table B-3, appendix B, if a description of the type of system is known.

Once this preliminary information is gathered, the following procedures can be applied.

Using the given information, table 4-1, and the material previously covered in this chapter, the following equations for heating and cooling energy use are derived:

Heating Energy Use (Btu/year) = ______ $Btu/HDD/ft^2$ x ______ HDD x ______ ft^2 ÷ heating efficiency factor

Cooling Energy Use (Btu/year) = ______ $Btu/CDD/ft^2$ x ______ CDD x ______ ft^2 ÷ Coefficient of Performance

Electrical Use (kWh/year) = ______ $watts/ft^2$ x ______ annual operating hours ÷ 1,000 Watt/kW

In this example, natural gas is used for heating buildings A, B, and D. Using the Heating Energy Use equation, the gas use in Btu for each of these buildings can be estimated:

Building A

Heating Use = 15 $Btu/HDD/ft^2$ x 4,000 HDD x 10,000 ft^2 ÷ 0.8 = 750 MBtu

Building B

Heating Use = 20 $Btu/HDD/ft^2$ x 4,000 HDD x 2,000 ft^2 ÷ 0.8 = 200 MBtu

Building C - None

Building D

Heating Use = 10 $Btu/HDD/ft^2$ x 4,000 HDD x 10,000 ft^2 ÷ 0.8 = 500 MBtu

Total = 1,450 MBtu

The preceding figures for natural gas usage by building are now used to proportion the total annual usage. These figures are estimates, not the acutal energy-use figures; actual use will be determined later. To proportion the gas use, the following procedure applies:

Building A $\frac{750 \text{ MBtu}}{1,450 \text{ MBtu}}$ (Total) x 2,000,000 ft^3/year = 1,034,000 ft^3/year

Building B $\frac{200 \text{ MBtu}}{1,450 \text{ MBtu}}$ x 2,000,000 ft^3/year = 276,000 ft^3/year

Building D $\frac{500 \text{ MBtu}}{1,450 \text{ MBtu}}$ x 2,000,000 ft^3/year = 690,000 ft^3/year

The proportioning of electrical use follows a procedure similar to that for proportioning natural gas. However, in this example, more than one building function is consuming electricity in each building.

Building A - Housing

Lighting = 1.0 watt/ft^2 x 10,000 ft^2 x 3,000 hours/yr ÷ 1,000 watts/kW = 30,000 kWh/year

Appliances = 1.0 watt/ft^2 x 10,000 ft^2 x 3,000 hours/yr ÷ 1,000 watts/kW = 30,000 kWh/year

Building B - Administration

Lighting = 3.0 watts/ft^2 x 2,000 ft^2 x 2,500 hours/yr ÷ 1,000 watts/kW = 15,000 kWh

Power = 0.5 watts/ft^2 x 2,000 ft^2 x 2,500 hours/yr ÷ 1,000 watts/kW = 2,500 kWh

Cooling = 20 Btu/CDD/ft^2 x 2,000 CDD x 2,000 ft^2 ÷ 3,413 Btu/kWh ÷ 2.5 (COP) = 9,400 kWh

Building C - Maintenance

Lighting = 1.0 watts/ft^2 x 50,000 ft^2 x 1,000 hours/yr ÷ 1,000 watts/kW = 5,000 kWh

Heating = 10 Btu/HDD/ft^2 x 4,000 HDD x 5,000 ft^2 ÷ 3,413 Btu/kW ÷ 0.8 (HEF) = 73,300 kWh

Building D - Industrial

Lighting = 2 watts/ft^2 x 10,000 ft^2 x 3,000 hours/yr ÷ 1,000 watts/kW = 60,000 kWh

Power = 2 watts/ft^2 x 10,000 ft^2 x 3,000 hours/yr ÷ 1,000 watts/kW = 60,000 kWh

Total 284,500 kWh

The electrical use estimates are now used to proportion the actual electric use. The actual total annual electric use was given as 200,000 kWh/year.

$$\frac{\text{Estimate Electrical Use (by Building)}}{\text{Estimated Total Electrical Use}} \times \text{Actual Total Electric Use} =$$

Actual Electric Use (for given building)

Building A $\frac{60{,}000 \text{ kWh}}{284{,}500 \text{ kWh}} \times 200{,}000 \text{ kWh} = 42{,}200 \text{ kWh}$

Building B $\frac{26{,}900 \text{ kWh}}{284{,}500 \text{ kWh}} \times 200{,}000 \text{ kWh} = 18{,}800 \text{ kWh}$

Building C $\frac{78{,}300 \text{ kWh}}{284{,}500 \text{ kWh}} \times 200{,}000 \text{ kWh} = 55{,}000 \text{ kWh}$

Building D $\frac{120{,}000 \text{ kWh}}{284{,}500 \text{ kWh}} \times 200{,}000 \text{ kWh} = 84{,}000 \text{ kWh}$

Total = 200,000 kWh

The energy use by each building can now be determined:

Building A Gas $= 1{,}034{,}000 \text{ ft}^3 \times 1{,}030 \frac{\text{Btu}}{\text{ft}^3} =$ 1,065 MBtu

Electric $= 42{,}200 \text{ kWh} \times 3{,}413 \frac{\text{Btu}}{\text{kWh}} =$ 144 MBtu

Total = 1,209 MBtu

Building B Gas $= 276{,}000 \text{ ft}^3 \times 1{,}030 \frac{\text{Btu}}{\text{ft}^3} =$ 284 MBtu

Electric $= 18{,}800 \text{ kWh} \times 3{,}413 \frac{\text{Btu}}{\text{kWh}} =$ 64 MBtu

Total = 348 MBtu

Building C Electric $= 55{,}000 \text{ kWh} \times 3{,}413 \frac{\text{Btu}}{\text{kWh}} =$ 188 MBtu

Total = 188 MBtu

Building D Gas $= 690{,}000 \text{ ft}^3 \times 1{,}030 \frac{\text{Btu}}{\text{ft}^3} =$ 711 MBtu

Electric $= 84{,}000 \text{ kWh} \times 3{,}413 \frac{\text{Btu}}{\text{kWh}} =$ 286 MBtu

Total = 997 MBtu

CHAPTER V. ENERGY CONSERVATION OPPORTUNITIES (ECO's)

A. Introduction

Anything which uses or causes energy to be used in a facility represents a potential for energy conservation--whether that be a poorly insulated duct, lights too bright for the functions they are lighting, or south-facing windows unshaded in summer. By the time the survey phase of the energy conservation program for a facility has been completed, a list of such potential ECO's will have been accumulated.

What remains now is to determine which of these potential ECO's might be translated into actual ECO's for use in the implementation phase of the energy management program. This means conducting a cost/benefit analysis of each potential ECO through response to three specific questions: (1) How much energy and how much money per year will be saved by implementing a particular ECO? (2) How much money will it cost to implement the ECO? (3) How long in months or years will it take the manager to recover the cost of implementing the ECO through savings on utility bills (the payback period)?

It is the purpose of this chapter in the handbook to provide estimates for making such cost/benefit analyses in an orderly and reliable manner. The ECO's discussed on the following pages should correspond with most of the cost-effective ECO's available in typical correctional facilities. By applying the procedure for each potential ECO in the correctional facility surveyed, it should be possible to recommend those ECO's which can be implemented within the general confines of the facility budget.

1. Use of correctional facilities staff. All staff of the institution must be involved in the energy conservation program. This includes not only mid- and lower-level managers, but also correctional officers, counselors, food service personnel, etc. Without their support on a day-to-day basis, the program is destined for failure.

Correctional officers make up the largest proportion of institutional personnel, over 75 percent in some facilities, and as such must be included in the design, implementation and management of the program. Like many members of the prisoner population, some officers may not identify with the energy goals of the agency. Staff may not be supportive. If one of the goals is to reduce energy consumption, they may, like the inmates, provide little support. The program may achieve only a segment of its designed objectives.

They may support the energy program in principle but give it a low priority due to their other duties. They may perceive, which is correct, that their primary function is to provide security and control; not turning off lights, closing windows, resetting thermostats, etc.

To overcome the above problems, managerial staff need to involve all personnel in the energy conservation program. They must be included in its design and development. They should be encouraged to offer suggestions no matter how untechnical or infeasible they initially appear. Experience has demonstrated that line staff often are aware of energy-wasting situations. Interested staff should also be represented on the Energy Conservation Team (ECT) and serve as a permanent part of the team once it has become a regular fixture in the institution. They, like the inmate population, should also be included in any savings incurred by the program. This would be rebated through increased salaries, increased benefits, etc. Other personnel must also be considered if the program is to be a success. For example, the education department could be instructed to develop an energy education program for both staff and residents; dietary staff could be informed of various energy saving methods of using proper food preparation and storage devices, and so on. The overall objective must be to involve as many staff as possible knowing that the negligence of only one staff member can hinder the accomplishments of the best designed program.

2. Use of resident labor. In Chapter II, (paragraph A6), the role of prisoner work groups was discussed as it relates to the development and management of an energy conservation program. In this section, attention is given to the use of inmate labor for energy conservation opportunities.

As has been emphasized throughout this document, the prisoner population must be motivated to support the energy savings program if it is to even get off the ground. The same is true in utilizing resident labor to develop and operate a myriad of energy conservation opportunities. These could include the following:

a. Participation in the Energy Conservation Team (ECT)

b. Support of energy conservation practices
   Lowering of thermostats
   Reduction of hot water usage
   Closing windows and doors

c. Assisting in retrofitting activities
   Caulking/weather stripping
   Insulating
   Reroofing
   Installation of solar panels
   Replacement of cracked windows/panes
   Replacement of filters

d. Manufacture/assemblage of energy conservation devices
   Solar panels/cells
   Wood burning stoves
   Wind turbines

B. Calculations for sample retrofit option (ECO)

In each option description, the following planning factors are described:

- Preliminary data collection
- Energy savings (in MBtu/year or kWh/year)

- Energy cost savings/year (in dollars)
- Capital cost of the retrofit.

Since it is these data that provide the basis for comparing retrofit projects, care should be taken to carefully follow the directions for the various calculations. Worksheet 3 has been provided to help organize the material necessary to complete the calculations associated with each of the options studied. Figure 3-8 provides an example of worksheet 3 completed using data from a case study.

For retrofit projects that have been previously planned for a building, a worksheet can be prepared that also includes this same information plus a brief description of the project itself.

For all the retrofit projects, those from this handbook plus those already planned for a facility, the simple payback period (SPP) should be calculated as an initial step in comparing the options. This can be accomplished with the information and instructions for cost calculations that accompany each individual option description. The SPP determines the time period it will take a project to pay for itself in energy dollars saved.

$$\text{SPP (years)} = \frac{\text{Total capital cost of retrofit project}}{\text{Net dollar savings per year}}$$

The option descriptions in this handbook call for the calculation of SPP as individual options are examined. Once all the options for an entire facility have been examined, the data for comparing them can be entered on worksheet 4 as shown in the example in figure 3-9. Be sure that the retrofit projects have been placed in order of priority based on SPP. Where two or more options have the same SPP, the highest priority should be given to those that maximize the ratio of Btu saved per year/retrofit project investment cost. Reproducible blanks for worksheets 3 and 4 are available in appendix A.

All projects which are subsequently selected from the worksheet 4 list for actual engineering design and funding should have a life-cycle cost analysis done based on the actual engineering design.

C. Retrofit Options

The remainder of this chapter consists of detailed explanations of the 38 retrofit options previously listed in figures 3-4 through 3-7. Each option has been assigned to one of seven major categories - Heating, Ventilation, Cooling, Lighting, Water Heating, Architectural, and Miscellaneous. Each option has also been identified by its category letter (e.g., A-Architectural).

HEATING OPTIONS

H-1. INSULATE HOT BARE HEATING PIPES

H-2. INSULATE STEAM LINES

H-3. RETURN STEAM CONDENSATE TO BOILER

H-4. INSTALL AND/OR REPLACE STEAM TRAPS

H-5. PREHEAT COMBUSTION AIR

H-6. REPLACE WORN BOILER CONTROLS

H-7. INSTALL BOILER OXYGEN ANALYZING EQUIPMENT

H-8. PREHEAT BOILER FEEDER WATER

1. HEATING OPTIONS (H)

The following options are suggested to help decrease the heating energy use in buildings.

If a building is supplied steam and/or hot water from a boiler or furnace located in another building apart from the building being surveyed, that heating system can be surveyed and included in the survey report. Also, care must be exercised with the stack economizer option not to reduce the flue gas temperature below 350°F for fuel oil and 250°F for natural gas. Temperatures below these recommended levels can cause condensation to be formed in the exhaust stack. This condensation can produce sulfuric acid and cause considerable damage to the stack.

Under some circumstances, project evaluation may need to take into account the cumulative effect of doing more than one option. For instance, if the first option considered can save 10 percent of the energy used for heating, remember to deduct that 10 percent from the energy savings calculation on the next option that is considered. This is done by reducing by 10 percent the total energy used for heating before proceeding with calculations for the second option considered. To properly evaluate the impact of particular options in relation to each other, calculate the energy savings on all options affecting a particular energy source before taking into account the cumulative effect of doing more than one option. Then, to improve the accuracy of the calculations, the cumulative effect should be estimated by starting with the option having the most attractive SPP, reducing the total Btu use by its effect, applying the next option to the reduced Btu usage, and continuing in this manner through the remaining options on the list.

As an example, suppose that Option H-1 (Insulate Heating/Cooling Pipes and Suction Lines) is considered and a calculation of energy saving shows that a saving of 1,000 gallons of oil is possible by doing this option. If the original oil uses was 10,000 gallons per year, the net result would be a use of 9,000 gallons after implementation of this option. If Option H-2 (Insulate Steam Lines) is then considered, the cost saving calculation should be based on 9,000 gallons of oil and not on the original use of 10,000 gallons, if Option H-1 has a lower SPP.

H-1 INSULATE HEATING/COOLING PIPES AND SUCTION LINES

Substantial energy savings will result from insulating the pipes that convey heating or cooling water through unconditioned spaces. Also, the insulation of steam condensate return pipes should not be overlooked. The addition of insulation will reduce the transfer of heat to and from the surrounding air and thereby reduce the load on the heating and/or cooling equipment.

If bare pipes are in areas to be heated, then the heat is not actually lost. However, the heat can be distributed and used much more efficiently it is is delivered to the intended equipment and not lost along the way through bare pipes.

As the temperature difference between the water in the pipe and the air surrounding the pipe increases, so does the heat transfer and economic effectiveness of an insulation retrofit. Pipes which are exposed to very hot or very cold air, such as those which run exterior to a building or in an attic or crawl space, will benefit most from the addition of insulation.

Typical insulation materials include rigid or semirigid tubes and flexible wrappings of fibrous, cellular or bonded form. These materials, properly installed, will last the lifetime of the piping.

Care should be taken that the selected insulation complies with applicable fire and smoke hazard standards and with local health and safety codes.

a. <u>Preliminary data collection</u>

To determine the energy saved by insulating pipes, refer to figures 5-1 and 5-2 for heating and figure 5-3 for cooling and carry out the following procedure:

- Tabulate all diameters and lengths of pipe to be insulated.
- Select the appropriate graph for the surface temperature of the pipe to be insulated.
- Enter the graph at the appropriate pipe size, intersect with the existing insulation thickness line, and read out the energy loss in Btu/hour.
- Repeat this procedure for the same size pipe, but intersect with the added insulation thickness line and read out the annual energy loss in Btu/hour.
- The difference between these two figures is the energy saved per hour for insulating each foot of the pipe size being treated.
- Multiply by the length of pipe to be insulated to obtain the total hourly saving.
- Repeat the above procedure for each different size of pipe.

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Figure 5-1. Heating - Heat Loss for Various Pipe Sizes, Insulation Thickness, and Water Temperatures from 100° F to 180° F

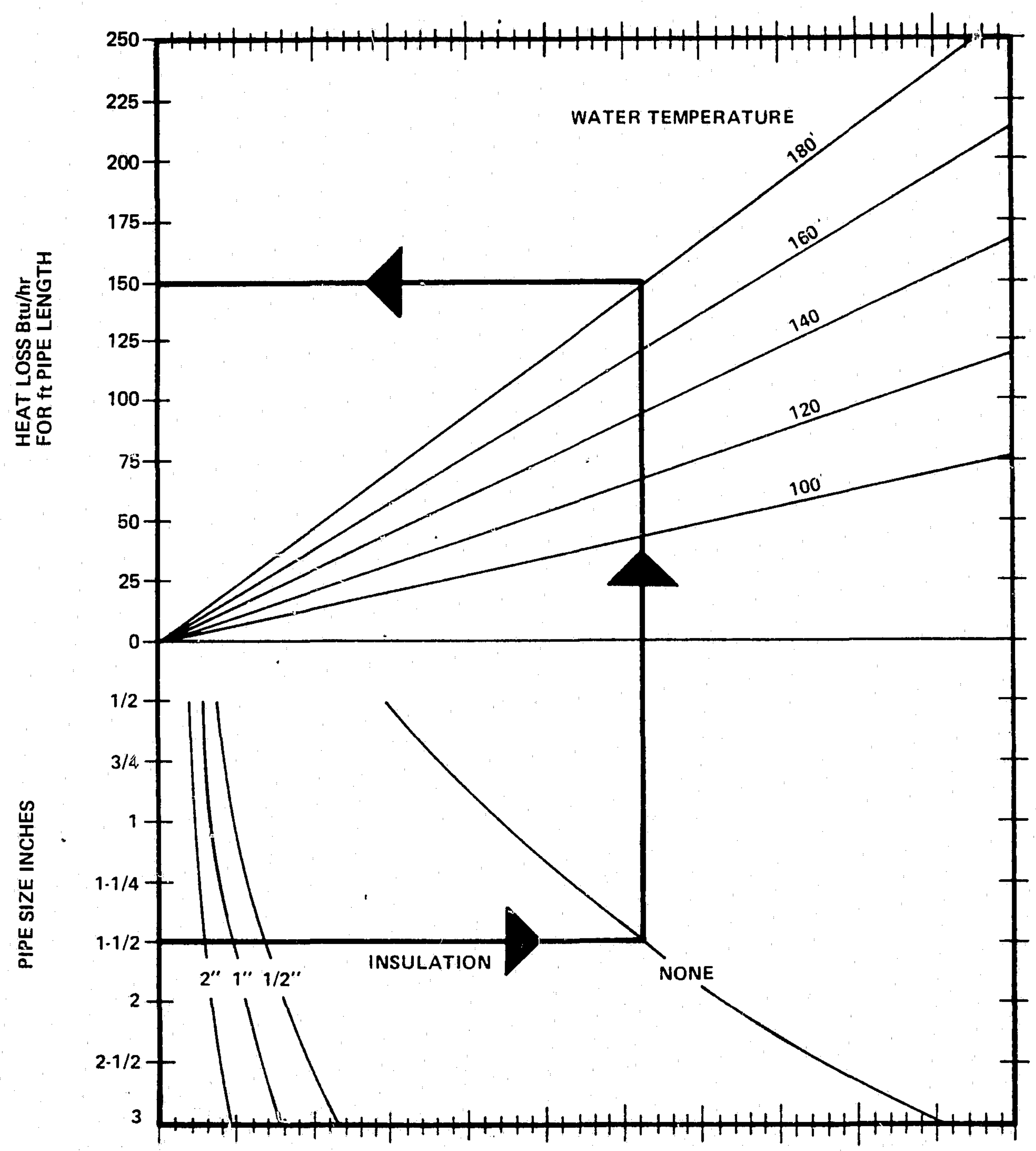


Figure 5-2. Heating - Heat Loss for Various Pipe Sizes, Insulation Thickness, and Water Temperatures from 200° F to 350° F

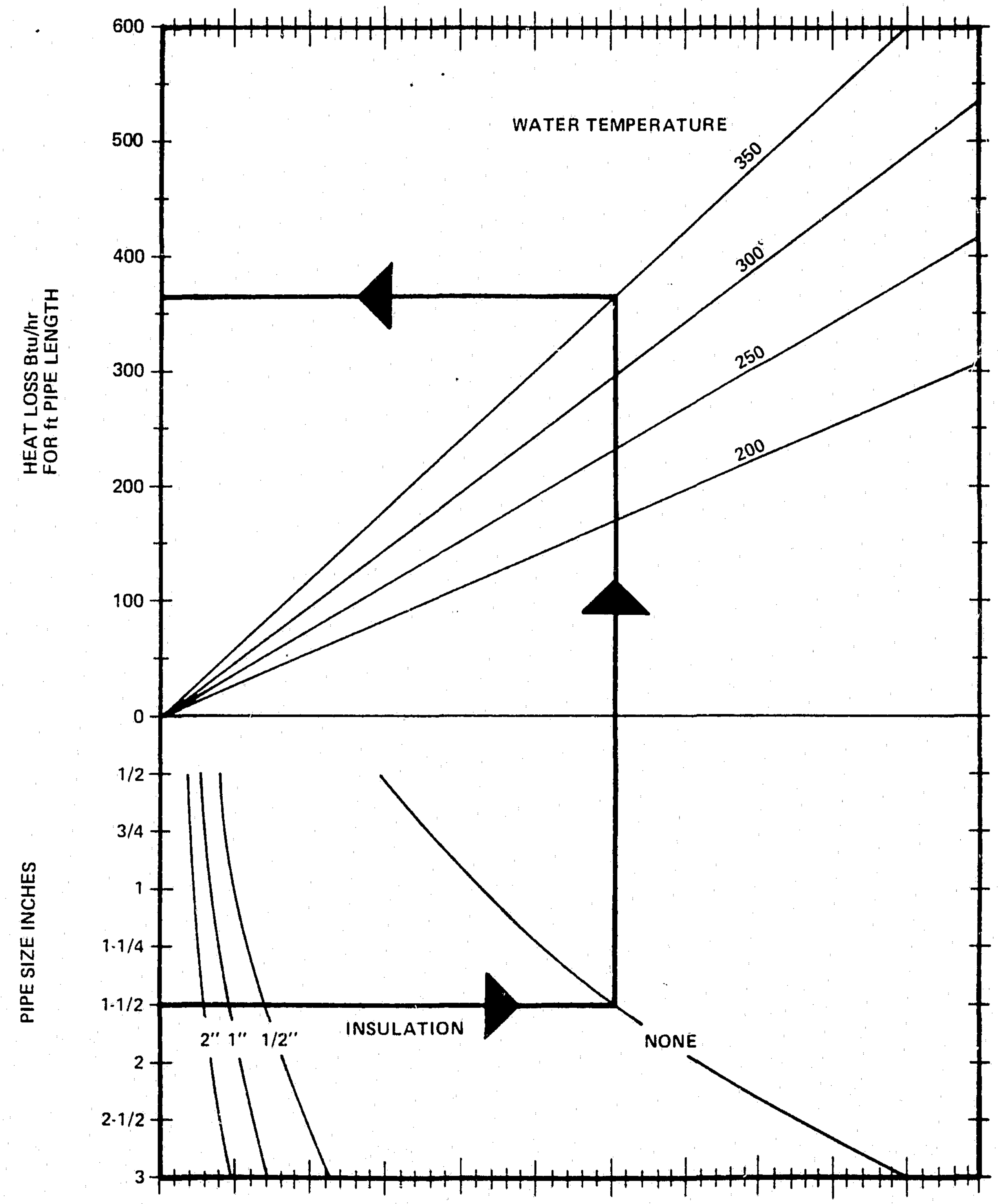
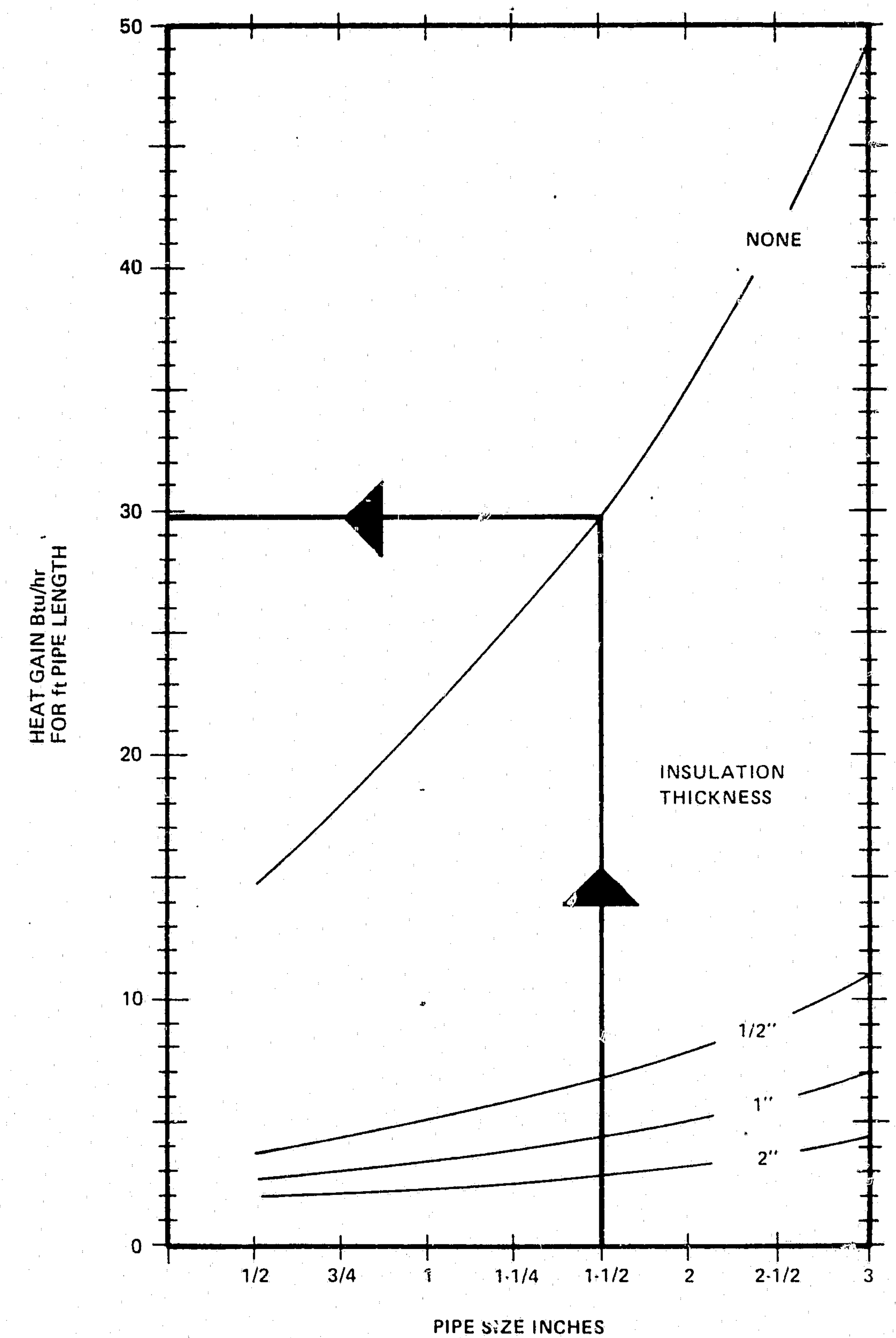


Table 5-1. Regional Weather Data

	Average Heating Season Temperature	Heating Season Length in Hours	Cooling Season Length in Hours	Average Cooling Season Temperature
Albany, NY	39°F	5544	3192	75°F
Albuquerque, NM	45°F	4200	4536	80°F
Atlanta, GA	48°F	3696	5040	79°F
Bismarck, ND	35°F	5712	3024	78°F
Boise, ID	42°F	5376	3360	78°F
Boston, MA	40°F	5544	3192	75°F
Billings, MT	41°F	5712	3024	77°F
Buffalo, NY	39°F	5544	3192	74°F
Charleston, SC	51°F	3024	6048	79°F
Chicago, IL	38°F	5208	3528	76°F
Corpus Christi, TX	56°F	1512	7224	81°F
Dallas, TX	49°F	3024	5712	83°F
Denver, CO	42°F	4872	3864	77°F
Detroit, MI	38°F	5544	3192	75°F
Ellsworth, SD	39°F	5376	3360	77°F
Fairchild, WA	40°F	6048	2688	75°F
Greensboro, NC	46°F	4032	4704	79°F
Helena, MT	38°F	6216	2520	75°F
Kansas City, MO	42°F	4368	4368	80°F
Kodiak, AK	40°F	8568	168	67°F
Las Vegas, NV	50°F	2856	5880	88°F
Los Angeles, CA	57°F	3192	5544	71°F
Louisville, KY	44°F	4368	4368	80°F
Lubbock, TX	46°F	3528	5208	80°F
Memphis, TN	47°F	2696	5040	81°F
Miami, FL	58°F	336	8400	80°F
Minneapolis, MN	35°F	5544	3192	76°F
New Orleans, LA	54°F	5376	6720	80°F
Omaha, NE	38°F	4872	3864	78°F
Pearl Harbor, HI	62°F	0	8736	80°F
Phoenix, AZ	53°F	1848	6888	87°F
Pittsburgh, PA	41°F	5040	3696	75°F
Portland, ME	40°F	6216	2520	73°F
Portland, OR	49°F	6048	2688	72°F
Roosevelt Rds, PR	62°F	0	8736	83°F
Sacramento, CA	49°F	5376	3360	79°F
San Diego, CA	58°F	3696	5040	70°F
San Francisco, CA	52°F	4704	4032	71°F
Traverse City, MI	37°F	5880	2856	74°F
Tulsa, OK	45°F	3696	5040	81°F
Washington, DC	44°F	4704	4032	77°F

Figure 5-3. Cooling - Heat Gain for Various Pipe Sizes



o Determine from table 5-1 the average winter or summer ambient air temperatures (°F) for your area for pipes exposed to the environment. If the pipe runs through a fully or partially conditioned space, use the estimated average winter and summer space temperatures, for example: 65°F and 78°F, respectively. Also, find your heating or cooling season length in hours.

o Measure or estimate the total heating efficiency factor, HEF for heating pipes (see appendix B, table B-3)

o Measure or estimate the total cooling efficiency factor, CEF for cooling pipes. (See appendix B, table B-3).

b. Energy savings (MBtu/year)

Energy savings (MBtu/year) = Heat loss savings* of the pipe insulation (Btu/hr) x

$$\frac{\text{Heating Season (hours)}}{\text{HEF} \times 10^6}$$

c. Energy cost savings/year = Energy savings (MBtu) x $/MBtu.

d. Capital cost ($) = Use table 5-2 to estimate the installed cost of insulation. If the proposed retrofit is the addition of more insulation to an insulated pipe (e.g., exposed to extreme temperature), use the outside diameter (pipe and insulation). The capital cost equals the product of the installed cost per foot of selected insulation and the length of pipe.

*Heat gain savings if the pipe is carrying chilled water.

Unit Heat Loss is based on a 65°F ambient temperature in figures 5-1 and 5-2 and Unit Heat Gain on a 78°F ambient temperature in figure 5-3. If this is not a reasonable temperature estimate, the true heat loss (gain) is given by:

From figure 5-1 and 5-2

$$\text{True Unit Heat Loss Savings} = \frac{\text{°F assumed}}{\text{°F ambient}} \times \text{Heat Loss Savings from Figure 5-1 and 5-2}$$

From figure 5-3

$$\text{True Unit Heat Gain Savings} = \frac{\text{°F ambient}}{\text{°F assumed}} \times \text{Heat Gain Savings from Figure 5-3}$$

Sum the heating and cooling season energy savings to obtain the total energy savings.

Table 5-2. Installed Costs of Pipe and Line Insulations/Linear Foot*

Pipe Insulation				Suction Line Insulation			
Pipe Diameter (Inches)	Insulation Thickness (inches) 1/2	1	2	Line Diameter (Inches)	Insulation Thickness (inches) 1/2	1	2
				1/4	$2.05	$2.35	$2.80
1/2	$1.50	$2.00	$3.70	1/2	2.10	2.45	3.70
3/4	1.55	2.10	3.95	3/4	2.15	2.55	3.95
1	1.65	2.20	4.15	1	2.20	2.80	4.15
2	2.15	2.70	4.75	2	2.60	3.25	4.75
3	2.50	3.10	5.45	3	3.25	4.65	5.75
4	2.95	3.90	6.40	4	4.25	6.25	6.90
5	3.30	4.30	7.20	5	5.55	7.85	9.50
6	3.50	4.80	7.75				
8	4.45	6.45	9.55				
10	4.85	7.20	11.15				
12	5.30	8.30	12.25				

Based on R-6 per inch of insulation.

Source: Mechanical and Electrical Cost Data, 1980, R.S. Means Co., Inc.

*These are average installation costs of fibrous insulation, including labor and material, for pipe located in accessible areas.

H-2. INSULATE STEAM LINES

The insulation of steam lines, especially in unheated areas, can save large amounts of energy in a steam distribution system. The addition of 1 inch of insulation can decrease the heat loss by 85 percent. Buried lines that are inaccessible should be excluded from this survey because of the difficulty in checking their condition.

If the bare pipes are in areas that are to be heated, then the heat is not actually lost. However, the steam can be distributed and used much more efficiently if it is delivered to the heat exchanger or process for which it was intended and not lost along the way through uninsulated lines. When the uninsulated lines pass through areas that are not to be heated, then the heat from them is truly lost from the system.

a. Preliminary data collection

- o Determine the operating steam pressure from boiler room personnel.
- o Measure or estimate the lengths of uninsulated steam lines, and the outside diameter. Even if the line is insulated leaving the boiler, it should be traced to the end use to make sure it is insulated for the entire length.

b. Energy savings (MBtu/year)

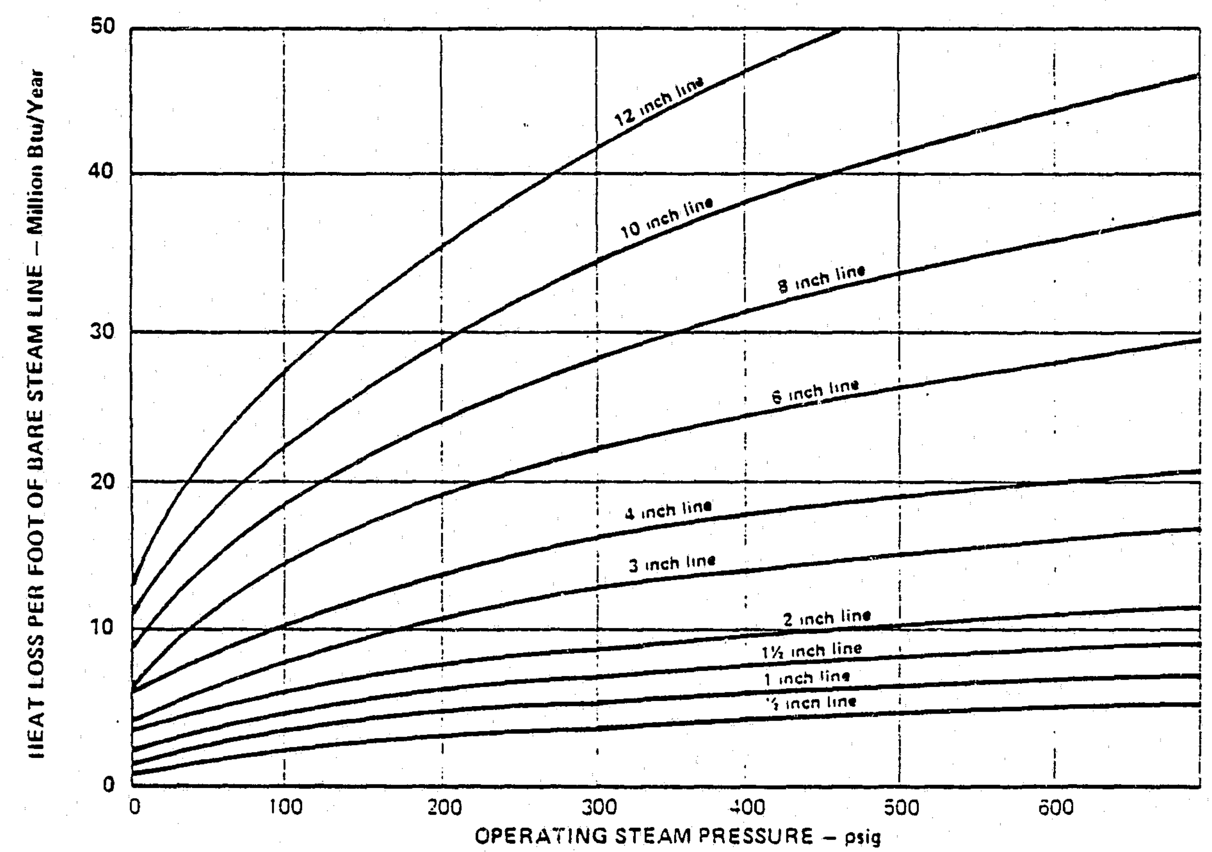
To find the energy savings, refer to figure 5-4 and estimate the heat loss for the total lengths of bare pipe. Assume that 85 percent of the heat loss can be eliminated by installing 1 inch of insulation.

Energy savings (MBtu/yr) = 0.85 x total heat lost through the bare pipe.

c. Energy cost savings/year = energy savings (MBtu/year) x \$/MBtu.

d. Capital cost (\$) - See table 5-2 (option H-1) for the calculation of estimated cost of insulation.

Figure 5-4. Heat Loss from Bare Steam Pipes



H-3. RETURN STEAM CONDENSATE TO BOILER

After steam is used in a system, it condenses to water. By returning the steam condensate to the boiler, the amount of makeup water required is reduced. Energy is saved since the condensate return water is at a high temperature and thus requires less energy to turn it back into steam.

a. Preliminary data collection.

- o Find out if the condensate is now returned to the boiler or have a mechanical engineer check the system.
- o If the water is not being returned, an estimate of the amount of condensate not being returned to the boiler can be obtained by determining how much water (in gallons) must be added to the system to keep steam supplied at operating levels (this is known as the makeup water). Use 0.8 x the number of makeup gallons per year to estimate the number of gallons of condensate that can be returned to the boiler.
- o Measure or estimate the total heating system energy efficiency (HEF). (See appendix B - table B-3).
- o Determine the number of hours the steam boiler(s) operate annually.

b. Energy savings (MBtu/year) = 1100 Btu/gal x number of gallons to be returned per hour x $\frac{\text{number of hours of boiler operation/year}}{\text{HEF} \times 10^6}$

c. Energy cost savings/year = Energy Savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - A mechanical contractor can provide the cost estimate to perform the necessary piping changes. It will most likely cost in the area of $10 to $15 per linear foot of pipe used. If insulation is applied, see table 5-2 (option H-1) for additional costs per linear foot.

H-4. INSTALL AND/OR REPLACE STEAM TRAPS

A steam trap is a device that removes condensate in steam lines by allowing liquid to pass through it, while not allowing steam to escape. Installing additional steam traps in lines, or replacing existing traps that are not functioning*, can pay back in less than 1 year. A malfunctioning trap will allow steam to pass through it as well as the condensate and thus wastes energy.

a. Preliminary data collection.

- o Determine the type of steam trap repair program used. If it is determined that only steam trap breakdown maintenance is being performed and no preventive maintenance program exists, it can be assumed that 10 percent or more of the traps are functioning improperly. A more accurate method of evaluating steam traps is to rent or purchase test equipment and perform in-hours checks of the traps.
- o Determine (estimate) the number of steam traps functioning improperly, and tabulate the trap orifice sizes and corresponding operating steam pressures. Do this for new traps and for those to be replaced.
- o If the orifice size is unknown assume a 3/16-inch diameter.
- o Determine the annual hours of operation for the steam system.
- o Measure or estimate the total heating efficiency factor (HEF). (See appendix B - table B-3)

b. Energy savings (MBtu/year) - Figure 5-5 can be used to estimate the amount of energy being lost from malfunctioning steam traps and its associated costs. For each trap studied, enter the graph at the appropriate orifice size, intersect with the system steam operating pressure, and read out the steam losses in lbs./hour from the left-hand margin.

c. Energy savings (MBtu/year) = lbs./hour for each trap x 970 Btu/lb. x $\frac{\text{annual number of hours of operation}}{\text{HEF} \times 10^6}$.

The cost of a malfunctioning trap or steam leak can also be obtained from figure 5-5. Enter the graph in the same procedure as that used to determine steam losses but intersect the appropriate fuel cost** line and read out in equivalent.

*The major steam trap manufacturers may provide free surveys of systems to determine which are not operating and where additional traps are needed. Steam trap testing equipment can be purchased or rented to identify improperly operating traps.

**Fuel cost = $\frac{\text{\$/MBtu (Actual Fuel Cost)}}{\text{HEF}}$

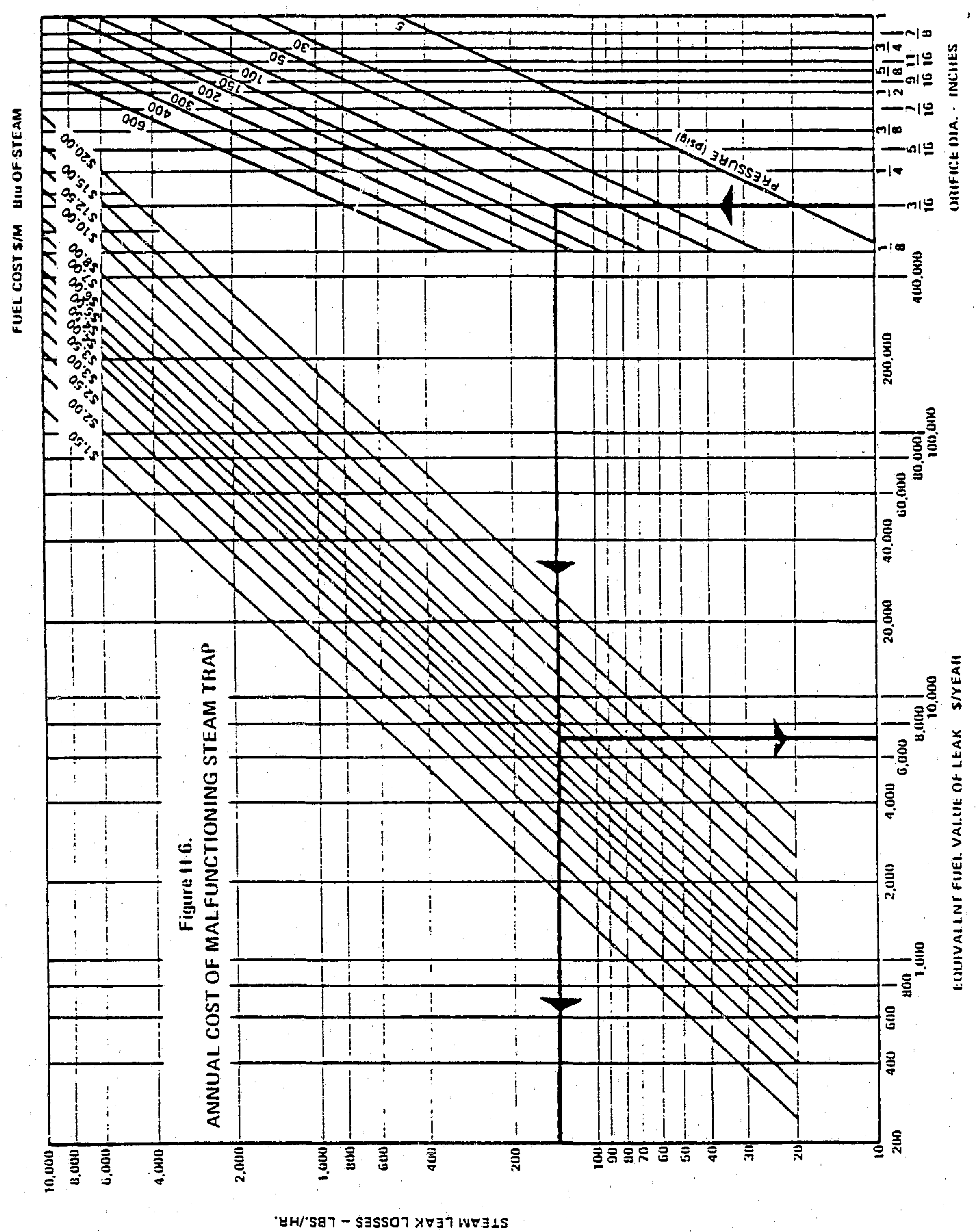


Figure 5-5. Annual Cost of Malfunctioning Steam Trap

Remember that the equivalent fuel value is based on a 12-month operation. Therefore, the energy dollar savings should reflect a percentage of the year the system is operational. The heavy line in the figure is provided as an example that indicates the value of a leak using a 3/16-inch diameter orifice, operating at 100 psig, with a fuel cost of $6/MBtu. The value of the example leak is approximately $7,000/year.

d. Capital cost ($). The cost for this option depends upon the type of traps needed for the system. Steam trap manufacturers can provide recommendations and cost estimates. Some sample price ranges are: $40 to $70/trap for a 1/2-inch line, $70 to $120 for a 1-inch line, and $220 to $240 for a 2-inch line. The larger and more complex traps can be rebuilt. However, the cost of replacement parts and labor can cause repair costs to almost equal that of a new trap.

H-5. PREHEAT COMBUSTION AIR

Preheating the combustion air with waste heat ordinarily discharged to the atmosphere can save up to 10 percent and more of the fuel used in a boiler or furnace. A preheater enables hot air to be introduced into the combustion chamber and saves energy by reducing the fuel needed to raise the boiler temperature the additional degrees to reach operating requirements. Not all boilers can be equipped with preheaters. The boiler manufacturer should be contacted to make sure that a preheater can be installed on the particular boiler being studied. The installation of an air preheater will reduce the flue gas temperature in the exhaust stack. Care should be taken in the design of the air preheater so that the flue gas temperature is not reduced below 250°F for natural gas and 350°F for other fuels (values below which condensation of water vapor or sulfur dioxide may occur in the stack). This condensation can produce sulfuric acid and cause considerable damage to the equipment.

a. Preliminary data collection

- o Determine if room is available for installation of a stack economizer. It usually requires about 1-2 cubic feet of space around the stack for small furnaces.
- o If possible, measure the stack temperature at the furnace; if it is above 250°F for natural gas furnaces, or 350°F for other fuels, an economizer is practicable. The 250°F or 350°F temperatures are recommended minimum flue stack temperatures.
- o From the nameplate, determine the rated input of the furnace, in Btu/hour.
- o If the stack temperature is unknown, assume a heat recovery potential of .15 (15 percent)
- o If the stack temperature is known (measured), use:
  Heat Recovery Potential =

$$\frac{\text{(Measured Stack Temperature - Room Temperature) - Minimum Flue Stack Temp °F}}{\text{(Measured Stack Temperature - Room Temperature)}}$$

- o Determine your annual hours of heating (see table 5-1). Assume about 1/3 of these hours annually, or estimate, based on knowledge of the unit, the annual hours of operation.
- o Determine boiler fuel usage.
- o Measure or estimate the total heating system efficiency (HEF) (see table B-3, appendix B).

b. Energy Savings (MBtu/year)

If the quantity of fuel used by the boiler is known:

Energy savings (MBtu/year) = quantity of fuel used x fuel conversion factor from table B-1 x heat recovery potential $\div 10^6$.

If the fuel usage is not known:

Energy savings (MBtu/year) = rated input (Btu/h) x annual hours of operation x heat recovery potential x (1-HEF) $\div 10^6$.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) To estimate the installation cost of preheating equipment, use $800 to $1,200 per million Btu/hr. input rating of the boiler. The unit price for this option will be greater for smaller boiler sizes. The boiler manufacturer can suggest specific air preheating equipment for a particular boiler.

CONTINUED

1 OF 3

H-6. REPLACE WORN BOILER CONTROLS

If the boiler is large enough to require a licensed operator, then the boiler control system is complex enough to greatly affect the efficient operation of the boiler. As the boiler control system approaches 10 years in age, the potential for defective operation from worn-out controls increases, and it may be possible to save energy by replacing the controls with a new system. If the present controls are worn, a new system could increase the efficiency of the boiler system by approximately 10 percent.

a. Preliminary data collection

- Determine if it is difficult to maintain the desired temperatures, pressures, flows, or exhaust gas oxygen content during boiler operations. If so, check the boiler nameplate for installation year. The boiler operator or boiler manufacturer can usually identify the age of the boiler controls.
- Obtain the boiler rating from the nameplate in millions of Btu/h.*
- Check the boiler fuel or steam usage log to determine annual fuel consumption.
- Calculate annual energy usage in MBtu by using the conversion factors found in appendix B.

b. Energy savings (MBtu/year) = 0.1 x MBtu used in boiler/year.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - As a rule of thumb, use between $500 and $600 per million Btu/h of boiler capacity as an estimated cost to replace controls. The boiler or control manufacturer can provide a more accurate estimate.

*Btu/h refers to the rating in Btu per hour and commonly appears on nameplates.

H-7. INSTALL BOILER OXYGEN ANALYZING EQUIPMENT

The addition of oxygen analyzing equipment which continuously monitors the quantity of oxygen in the boiler flue gas can improve the efficiency of the boiler. The monitoring of oxygen content will enable the boiler operator to fire the boiler with a minimum of excess air. Operating cost of the boiler will be reduced by at least 2 percent.

For larger boiler plants (greater than 10 million Btu/h per boiler) consider the installation of an automatic continuous oxygen analyzer with "trim" output that will adjust the fuel/air ratio to meet changing stack draft and load conditions.

Most boilers can be modified to accept control by a flue gas analyzer, but a gas analyzer manufacturer should be consulted for each particular installation to be sure that all other boiler controls are compatible with the analyzers.

It is important to note that some environmental protection laws might place a higher priority on visible stack emissions than on efficiency optimization of fuel combustion especially where fuel oil is concerned. The effect of percent total air on smoke density might prove to be an overriding consideration and limit the approach to minimum excess air. All applicable codes and environmental statutes should be checked for compliance.

a. Preliminary data collection.

- Check with the boiler operator to see if a recent combustion gas analysis has been performed. It is is above 6 percent oxygen, calculate the annual energy use in MBtu by using the annual fuel use and the conversion factors found in appendix B.
- Check the boiler fuel or steam usage log to determine annual fuel consumption.

b. Energy savings (MBtu/year) = .02 x MBtu used in boiler/year.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - Approximately $10,000 per unit for each boiler. (Including a chart recorder device).

H-8. PREHEAT BOILER FEED (MAKEUP) WATER

Preheating boiler makeup water before it enters the boiler by utilizing exhaust stack waste heat will reduce energy requirements for the boiler. Not all boilers can be equipped with preheaters and therefore, economizers should not be installed unless the manufacturer considers the installation sound. Care should be taken to assure the water makeup economizer in the stack is designed so that the flue gas temperature will not drop below 350°F (250°F for natural gas). Any flue temperature below 350°F could result in condensation of water vapor and sulfur dioxide which may result in the formation of sulfuric acid and cause damage to the equipment. Also, the addition of the economizer increases the resistance to air flow and thus an induced draft fan may be required.

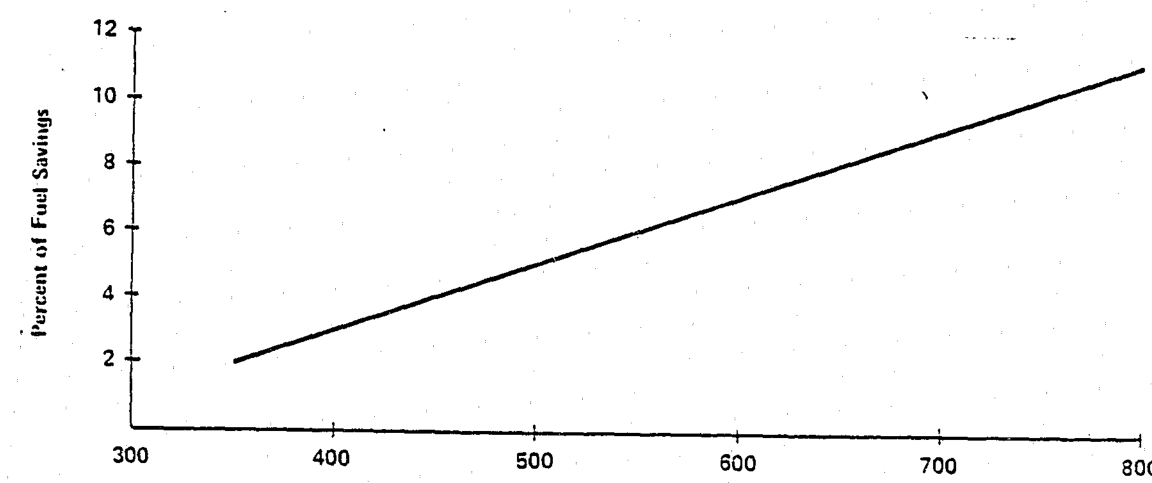
To determine the feasibility of adding a feedwater preheat system, the exhaust gas temperature of the boiler should be measured. This can be done using the existing gages, or be determined during the exhaust gas analysis. Boilers with stack temperatures of over 370°F can be considered candidates for the economizer option. An economizer should be considered for any boiler that operates more than 3,000 hours per year, and generates from 20,000 to 150,000 pounds of steam per hour. As the stack temperature increases, the potential savings will also increase. At a stack temperature of 800°F, the potential future savings can approach 12 percent.

a. Preliminary data collection

- o Check to see if any makeup water preheating is being done at the present time.
- o Check the boiler fuel, steam usage, and makeup water log to determine annual consumption.
- o Calculate annual energy use in MBtu by using the fuel usage and the conversion factors found in appendix B.
- o Determine stack temperature from boiler gages, or estimate the temperature from the manufacturer's specifications.

- o Enter figure 5-6 at the stack temperature and intersect the efficiency line to determine the percent of fuel savings possible with an economizer.
- o Check boiler nameplate to identify boiler size in millions Btu/h.

Figure 5-6. Potential Percentage Fuel Savings Through Economizer Use



b. Energy savings (MBtu/year) = Percent fuel savings x MBtu used in boiler/year.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - A quote for the economizer installation should be obtained from a contractor as local conditions vary considerably. Normally an economizer will cost $1,500 to $1,800 per million Btuh boiler rating, depending on the amount of heat to be recovered and the initial stack temperatures.

VENTILATION OPTIONS

V-1. CLOSE OFF UNOCUPPIED AREAS

V-2. SHUT DOWN AIR DISTRIBUTION SYSTEM

V-3. SHUT DOWN EXHAUST SYSTEMS

V-4. INSTALL AUTOMATIC THERMOSTATS

V-5. REDUCE AIR VOLUME

V-6. INSTALL ENERGY RECOVERY EQUIPMENT

2. VENTILATION OPTIONS (V)

a. A considerable amount of energy is used to move hot or cold air in correctional facilities. The options contained in this section suggest ways of reducing that energy use. As in other retrofit options, the implementation of one option will have an effect on the potential for energy savings in other options. This may be useful to consider when calculating energy and cost savings for the retrofit system.

In some cases, there will be a choice of options that will affect the same system. Where a choice between options must be made, it is advisable to do the calculations for both options, then select the one with the lowest simple payback period.

The options listed in this section will affect both heating and cooling systems. Therefore, by reducing the ventilating load, the load on the heating and cooling equipment will also be reduced.

V-1. CLOSE OFF UNOCCUPIED AREAS

In many prisons and jails, unoccupied areas are frequently heated (and/or cooled). This can occur when space use patterns change, for example, when an office is converted to storage space. These unoccupied areas can be closed off, with only sufficient heat being supplied to prevent freeze damage. If the closed-off area has four walls exposed to the exterior, all of the energy presently used can be saved. If the closed-off area is surrounded by conditioned space, for example, a storeroom on the interior of a conditioned building, the energy savings will be less.

The actual energy savings will depend on many factors including the wall construction materials, insulation factors, site characteristics, the number of exposed exterior walls, etc. To estimate the savings that could be achieved by closing off unoccupied areas, use the following:

SAVINGS FACTORS

Four exterior walls	1.00
Three exterior walls	0.85
Two exterior walls	0.65
One exterior wall	0.45
No exterior walls	0.30

Exceptions to this ECO include critical material storage areas with special temperature and humidity requirements, wet fire sprinkler systems without antifreeze, and other water piping subject to freeze damage. If the closed-off area will be heated only to avoid freeze damage to equipment or water systems, the retrofit system savings factor will be 0.70.

a. Preliminary Data Collection

- Determine if there are vacant or unoccupied areas that could be shut off. If the contents in any of these areas require critical temperature control, consider consolidating these items into one area and closing off the remaining areas.
- Measure the square footage of the unoccupied area.
- If available, determine the annual heating or cooling* energy use per gross square foot (gsf) from worksheet 1 and chapter 4.
- Determine the annual heating and cooling degree days (HDD or CDD)* (see figures 5-13 and 5-14, Option A-1).
- Measure or estimate the total heating or cooling system efficiency (HEF or CEF)* (see appendix B, table B-3).

*If cooling is employed, repeat the calculation for cooling energy savings. Sum the heating and cooling energy savings to obtain the total energy savings.

- Determine the number of exterior walls in the space to be closed.

b. Energy Savings (MBtu/year)

- If the energy use level is known:

Energy savings (MBtu/year) = unoccupied building area x heating energy use (Btu/gsf) x savings factor
or HEF x 10^6

- If the energy use level is not known, use the heating and cooling energy use estimates given in table 4-1, chapter IV, for the specific building type in Btu/gsf/degree day:

Energy savings (MBtu/year) = building type (heating Btu/gsf/HDD*) x unoccupied area x HDD* x savings factor
HEF x 10^6

c. Energy Cost Savings/Year = Energy savings (MBtu/year) x $/MBtu.

d. Capital Cost ($). In most cases, closing doors, dampers, or valves will shut off the heating to the space. Adding dampers or valves to the appropriate area heating supply may be required, or, in some situations, the construction of partitions at additional cost may be necessary.

The investment cost to close a door or damper, or to open a valve is $0. For estimating purposes, the cost of installing one damper is approximately $42. However, it is best to obtain an estimate from an HVAC (heating, ventilating, and air conditioning) contractor.

V-2. SHUT DOWN AIR DISTRIBUTION SYSTEM

There are two major types of air distribution systems; central duct systems and perimeter systems known as fan-coil units. Central duct systems are common in many types of buildings having forced air heating or cooling. Fan-coil units are found most frequently in administrative areas and hospitals. If it is possible to shut down the central duct system during unoccupied times, large energy and cost reductions are possible. A control can be installed in cold climates (Zones 1 and 2) to turn the system back on should the temperature drop too greatly in the building during the winter. This would be a safety feature to prevent damage to the interior. However, most of the time the system can be shut down without adverse effects. The installation of time clocks can accomplish this with a minimum investment cost. Select time clocks with 7-day features that will allow for weekend shutdown, and with a continuous-running feature that will allow them to maintain the correct time during a power outage. A manual override should be incorporated to permit unscheduled occupancy in the evenings and on weekends. If the time clocks have been installed, check whether or not they have a 7-day feature to shut down on weekends.

Fan-coil units can also be controlled by a time clock. In order for these to be controlled economically, they must be on common electrical circuits. If each fan-coil unit requires a separate time clock, then this option is not feasible.

a. Preliminary Data Collection

- Survey the building HVAC equipment usage pattern. Establish if units are left on during unoccupied hours, and estimate the hours per day that the units operate and the number of hours that the units could be shut down.

- Count the number of units involved and obtain the horsepower; voltage, amperage, and phase from the nameplate; or the kilowatt draw. The kilowatt draw (kW) can be found by:

$$kW = \frac{\text{Volts x Amps x Phase}^{\frac{1}{2}}}{1,000}$$

- If the volts, amperage and phase are not available, total the horsepower from the nameplate of all the motors that can be shut down. Whereas central duct systems will generally range from 1 to 25 hp per motor, fan-coil units usually have small motors (1/8 to 1/4 hp). An electrician can find out if the fan-coil units are on separate circuits. The kW draw can be estimated by:

$$kW = \text{total horsepower x 0.76 kW/hp}$$

b. Energy Savings (kWh/year)

Energy savings (kWs/year) = number of hours per year that the system can be shut down x kW draw.

c. Energy Cost Savings/Year = Energy savings (kWh/year) x $/kWh.

d. Capital Cost ($)

As an estimate, use $375 for each piece of equipment that requires the installation of a time clock. A time clock can switch one or more circuits, depending on the design. If the fan-coil units are not already on separate circuits, the cost to isolate these units onto separate circuits should be estimated by a contractor and included in the capital cost calculations.

V-3. SHUT DOWN EXHAUST SYSTEMS

Exhaust systems are used to remove odors or contaminated air from a building. Often the function which requires the exhaust operates only part of the time, thus the exhaust system could be shut down during periods when it is not needed. Energy savings are accomplished by reducing the quantity of outside air that must be tempered to replace the exhausted air and by limiting the running of the exhaust fan motors.

The exhaust system can be shut down with a minimum investment through the use of time clocks having a 7-day feature and allowing for weekend control (see retrofit option V-2).

a. Preliminary data collection

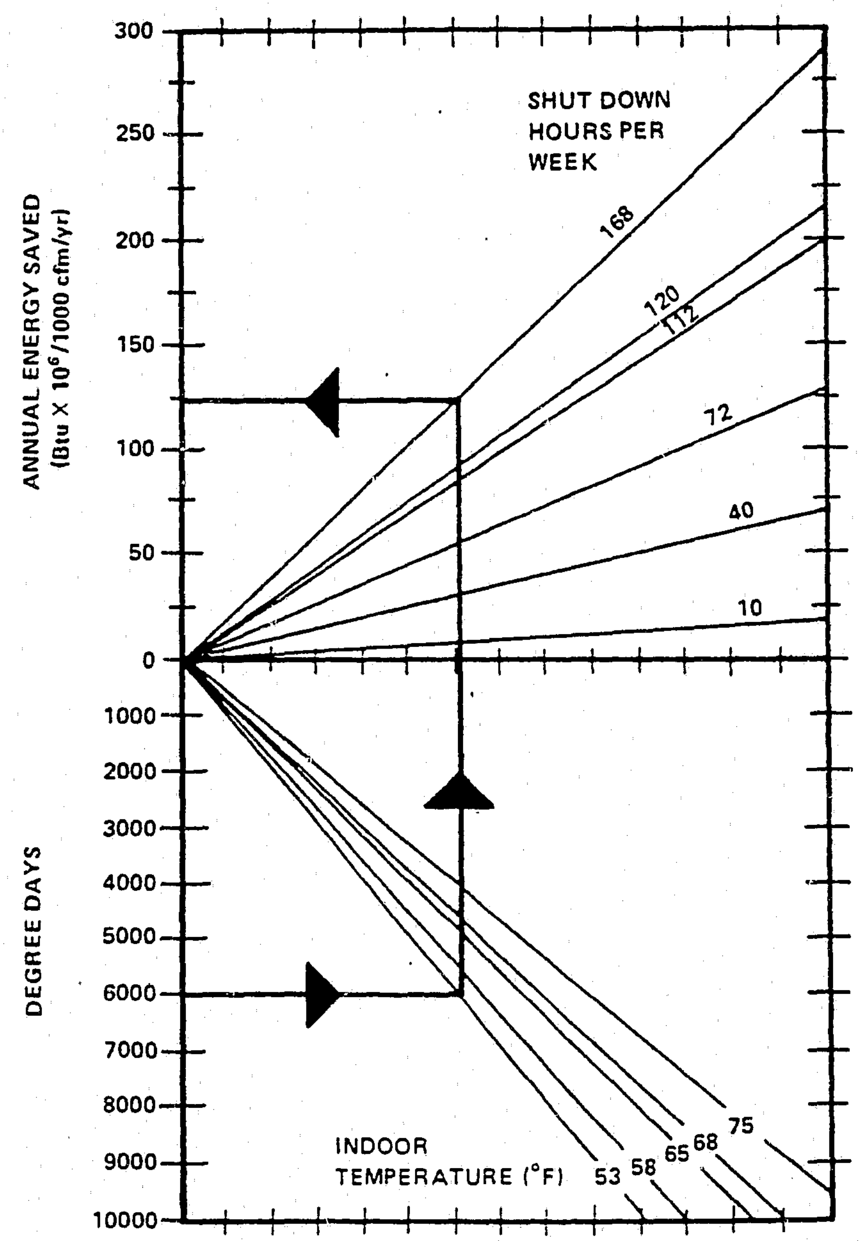
- o Survey the building when it is unoccupied to locate exhaust systems that are operating. Determine if the space from which they are exhausting air is not being used - some processes require continuous exhaust.
- o Count the number of units involved and obtain the unit air handling quantities in cfm from the building mechanical systems design plans.
- o Determine the annual heating degree days (HDD) (see figure 5-13).
- o Determine the indoor temperature that is being maintained.
- o For each unit, determine the present operating hours per week. Then determine the number of hours per week that each exhaust unit can be shut down.
- o Obtain the horsepower; the voltage, amperage, and phase from the nameplate data; or the kW draw.

b. Energy Savings (MBtu/year and kWh/year) =

- o Heating savings calculation: From figure 5-7 obtain heating energy savings. Enter the nomograph at the number of degree days that corresponds with the facility location. Intersect with the indoor temperature being maintained and follow the vertical line to the point where it intersects with the number of shutdown hours. Follow the example line across to heating energy savings in millions of Btu (MBtu) per 1,000 cfm.

  Heating energy savings (MBtu/year) = Annual energy saved (MBtu/1,000 cfm/year) x $\frac{\text{actual cfm}}{1000}$

Figure 5-7. Heating Energy Saved by Exhaust System Shutdown



o Electrical Savings Calculation:

The kW draw can be estimated by:

$$kW = \text{Total horsepower} \times 0.76 \text{ kW/hp}$$

or

$$kW = \frac{\text{Volts} \times \text{amps} \times \text{Phase}^{\frac{1}{2}}}{1000}$$

Electrical energy savings (kWh/year) = number of hours per year that the system can be shut down x kW draw.

c. <u>Energy cost savings/year</u>

Heating energy savings = (MBtu/year) x \$/MBtu + Electrical Energy Savings (kWh/year) x \$/kWh.

d. <u>Capital cost (\$)</u>. As an estimate, use \$375 for each exhaust system that requires the installation of a time clock.

V-4. INSTALL ENERGY-SAVING AUTOMATIC SETBACK THERMOSTATS

The installation of automatic setback thermostats can provide around-the-clock temperature control. This permits heating and related ventilating air flow to be reduced or eliminated when any area of a building is unoccupied at night or on weekends. As a rule, for heating, a reduction of each 1°F will decrease the heating energy use by 3 percent in buildings where temperature setback by thermostatic control is employed. If option V-2 (Shutting Down Air Distribution System) can be done, this option need not be considered.

Automatic setback thermostats are available in several models. Single setback or dual setback models are most generally used. The following data illustrates the setback features of both models and typical settings.

Single Setback Thermostat		Dual Setback Thermostat	
Daily (Adjustable)	Temp. Set Point	Daily (Adjustable)	Temp. Set Point
ON - 6:00 AM	65°F	ON - 6:00 AM -	65°F
Setback - 10:00 PM	55°F	Setback - 9:00 AM -	55°F
		ON - 4:30 PM -	65°F
		Setback - 10:00 PM -	55°F

Both types of setback models employ timing controls and manual override levers to setback the thermostat control point and/or set up the thermostat control point. These can be used if occupancy occurs and normal temperatures for occupied periods are desired during the setback period. The thermostat should be located on an inside wall and protected from drafts and solar effect. As a guide, administrative areas would require a single setback controller; residences, cells, and other buildings that are vacant during most of the normal working day would require a dual setback thermostat. Setback thermostats can also be used for controlling summer space temperatures in buildings where mechanical cooling is used.

In the case of multiple hot water heating units, the flow of tempered water can be controlled so that the temperature reduction is obtained. The flow is stopped by a solenoid valve in the supply water pipe which is controlled by a thermostat.

a. Preliminary data collection

- o Verify facility use patterns including the hours and days of operation to determine the feasibility of thermostatic setback of the heating and ventilating equipment.
- o Determine the annual heating degree days (HDD) (see figure 5-13).
- o Estimate the number of thermostats required; usually a one-for-one replacement with existing thermostats.

- o Estimate the gross square footage and determine actual heating energy use requirements for the building (see worksheet 2, and chapter IV).
- o Measure or estimate the total heating efficiency factor (HEF). (see appendix B, table B-3).

b. Energy savings (MBtu/year)

Determine the present heating energy use by:

- o If the energy use level (Btu/gsf/year) is known:

  Present heating energy use (MBtu/year) = Building area (gsf) x Actual MBtu/gsf/year

- o If the energy use level is not known, use the estimated building Btu/gsf/HDD (see table 4-1):

  $$\text{Present heating energy use (MBtu/year)} = \frac{\text{MBtu/gsf/HDD} \times \text{building area (gsf)} \times \text{HDD}}{\text{HEF}}$$

- o To determine the energy savings in Btu/gsf/year, enter the graph (figure 5-8) at the appropriate present heating energy and degree-day axis, intersect with the proper setback line, and follow the example line to determine the savings in Btu per square foot per year*. The possible setbacks for most buildings will range between 5° and 15°F. A temperature setting of 55°F is recommended during unoccupied hours.

  $$\text{Energy Savings (MBtu/year)} = \text{Future heating energy savings (Btu/gsf/year)} \times \frac{\text{Building area (gsf)}}{10^6}$$

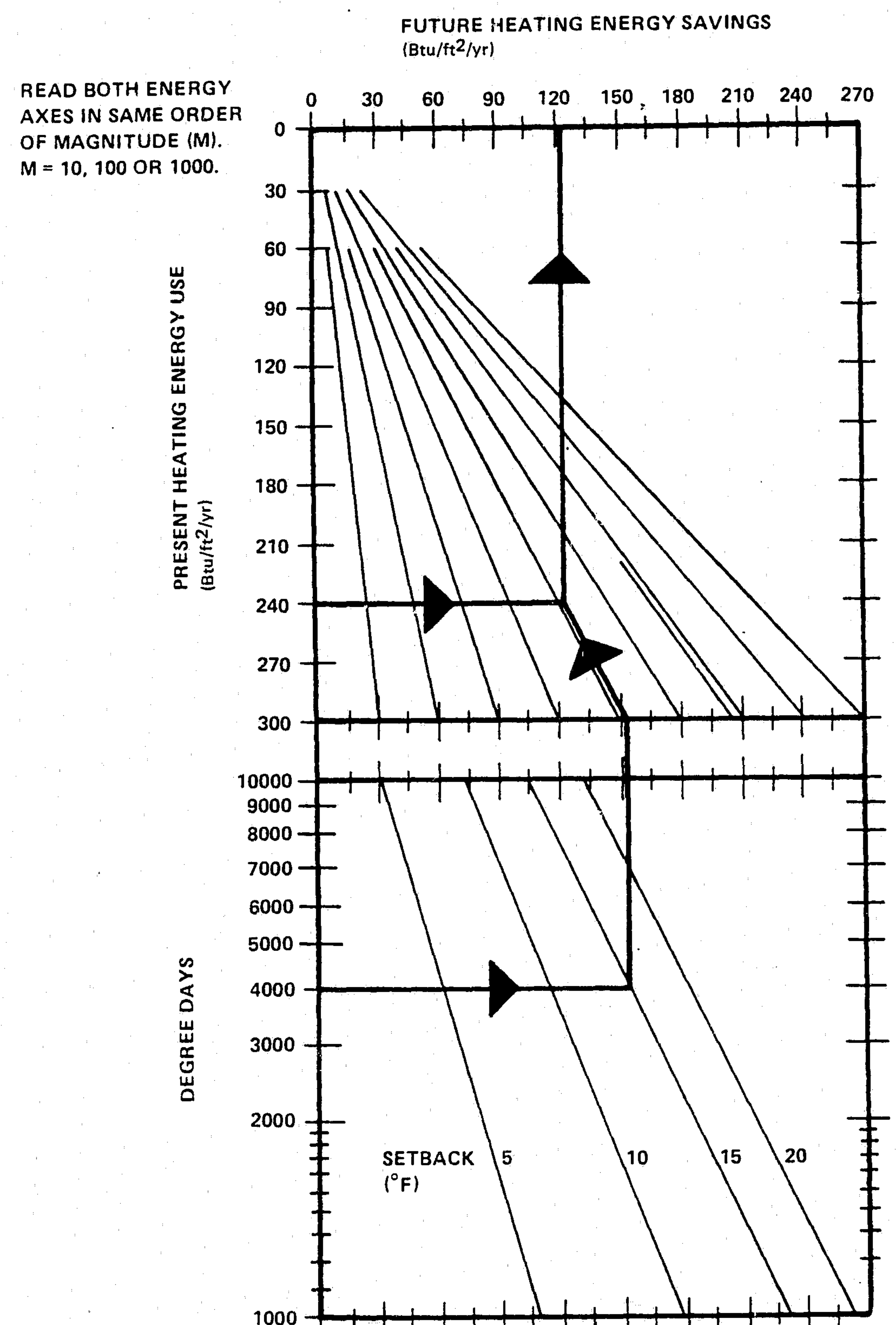
c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) = A single setback thermostat costs approximately $85 installed. Dual setback thermostats are $100 each. For better estimates, ask local sources for quotations. A solenoid water valve control should not be more than $1,000.

*Assumes a 16 hour daily setback. If this is not appropriate, the estimated energy savings can be calculated by:

$$\text{Actual savings} = \frac{\text{hours setback per day}}{16 \text{ hours}} \times \text{future heating energy savings}$$

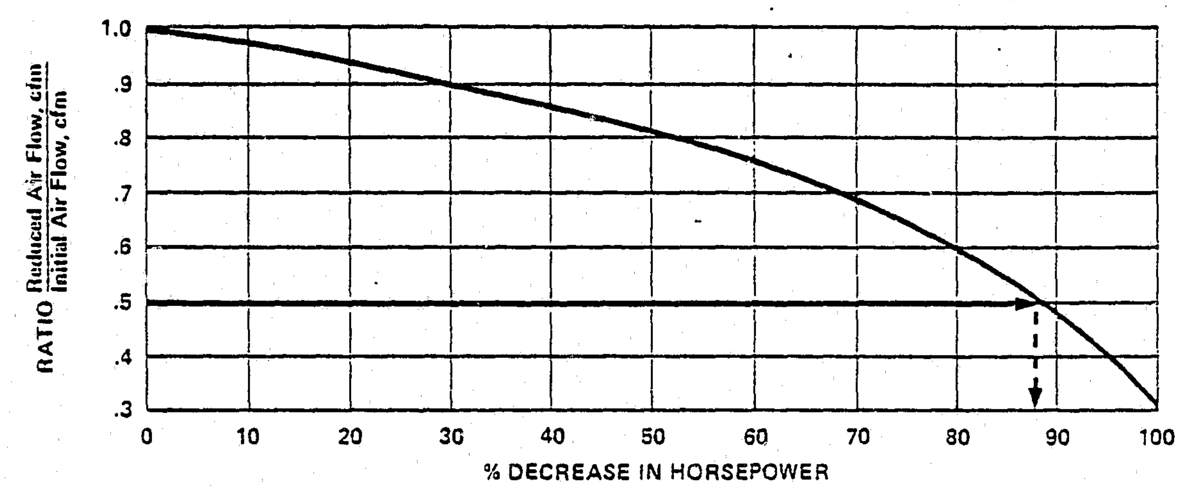
Figure 5-8. Heating Energy Saved by Night Setback



V-5. REDUCE AIR VOLUME

Air distribution systems often consume a large percentage of the total energy used in a building. By reducing the number of cubic feet per minute (cfm) delivered by the air distribution system through reduction in fan speed to the minimum level required by law, a great deal of this energy can be saved. The graph (figure 5-9) shows the potential large reductions in power compared to the reductions in volume (cfm). The vertical axis of the graph is the ratio of the reduced air flow to the initial air flow. In the example shown, reducing air flow by 50 percent reduced power use by 87.5 percent. Savings of this magnitude are not uncommon. This option should be applied to motors greater than 5 horsepower. Apply this option to central air distribution systems only and not to perimeter fan coil units. Reducing the air volume may also reduce the energy requirements for the heating and cooling equipment.

Figure 5-9. Decrease in Horsepower Accompanied by Reducing Fan Speed (Based on Legal Minimums)



a. Preliminary data collection

- For this option, information on the air flow for each fan must be available from building drawings or actually measured. If this cannot be done with in-house labor, then an HVAC contractor or consultant could do the measuring. They will also know the legal minimums for cfm delivery.

- The following steps are used to determine the decrease in required fan horsepower:

  Determine the initial air flow rate for each fan considered, in cfm.

  Determine the reduced air flow rate for the fans considered, in cfm.

Enter figure 5-9 at the vertical axis at the appropriate ratio of reduced airflow to initial airflow.

Move horizontally right to intersect with the horsepower curve and then vertically downward.

Read the percent decrease in horsepower on the horizontal axis.

- o To obtain the decrease in fan motor horsepower, multiply the percent decrease in horsepower by the rated horsepower of the fan motor.

b. Energy savings (kWh/year) = Decrease in fan motor horsepower x 0.76 kW/hp x number of operating hours/year for the fan. (This calculation does not include heating and cooling equipment energy savings).

c. Energy cost savings/year = Energy savings (kWh/year) x $/kWh.

d. Capital cost ($) - Once the amount of possible air reduction is known, it is a matter of slowing the fan down to the proper speed by changing the pulley or by changing the motor. In any case, it should not be more than $1,000 for each unit unless it is extremely large. Estimates for this work can be obtained from an air-conditioning contractor. Using a contractor to measure airflow will add an additional cost (approximately $500/day).

V-6 INSTALL ENERGY RECOVERY EQUIPMENT

Installing energy recovery equipment such as rotary heat wheels, exchangers, heat pipes, or other energy recovery systems can recapture heating or cooling energy in exhaust air before it is exhausted. If large amounts (70 to 100 percent) or outside air are required because of the large amount of air being exhausted, this is an attractive option. As much as 70 percent of the energy in the exhaust air can be recovered and transferred to the outside supply air.

a. Preliminary data collection

- o Find the areas where air is exhausted from the building.
- o Contact equipment manufacturers to see if it is practical to try to recover the energy. Usually if the intake of the system is over 10 feet from where the air is being exhausted, it is too costly to install the necessary equipment (except for coil run-around systems).

b. Energy savings (MBtu/year) - Information about the energy saved can be obtained from equipment manufacturers.

c. Energy cost savings/year - Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - The equipment and installation cost of this type of system requires a design for the particular building being studied. An A&E firm or an equipment manufacturer can estimate the cost. The cost should not exceed $3.00/cubic foot/minute.

COOLING OPTIONS

C-1. INSTALL TIME CLOCKS FOR AIR CONDITIONERS

C-2. REPLACE INEFFICIENT AIR CONDITIONERS

C-3. INSTALL TEMPERATURE CONTROLLER AND SENSOR

C-4. INSTALL ECONOMIZER CYCLE

C-5. CONTROL SOLAR HEAT GAIN

3. COOLING OPTIONS (C)

There are several types of cooling equipment used at prisons. The major types are: window units (usually in older buildings that were designed and built before the advent of central air-conditioning); central electric-driven compression units; and central steam or hot water absorption units. From an energy standpoint, the electric-driven unit is more efficient than the absorption unit, even including the energy used to produce the electricity at the power station. Absorption units, even if not as efficient as electric-driven units, are economically feasible, since fossil fuels are not burned to generate electricty.

Care must be taken when starting and stopping large cooling units at close intervals. If proper procedures are not followed, serious damage can be caused to the mechanical equipment. Consult equipment manufacturers for proper starting and stopping procedures.

Cooling retrofit options include those which modify the operation of the air-conditioning unit and those which reduce the load on the cooling equipment. In addition, automatic setback thermostats identified in option V-2 can be used to optimize the operation of central air-conditioning units. As with other options, the implementation of one option will have an effect on the potential energy and cost savings of other options.

C-1. INSTALL TIME CLOCKS FOR WINDOW AIR-CONDITIONERS (A/C)

The installation of time clocks to shut down window A/C units during unoccupied periods can save energy. The time clocks will also turn the units back on at the desired time. Time clocks should be of the 7-day type that will allow for total weekend shutdown. This option is particularly applicable to buildings where multiple units are served by a single electrical circuit; however, in some cases time clocks can be economically installed on single units. Time clocks with a spring backup can continue operating in the event of an electrical power failure.

a. Preliminary data collection

- o Determine which units are left on during unoccupied hours.
- o Estimate the number of hours the units could be turned off.
- o Count the units involved and obtain the voltage, amperage, and phase (1 or 3) from the nameplates.
- o The kW demand is given by:

$$kW = \frac{\text{Volts} \times \text{Amps} \times (\text{Phase})^{\frac{1}{2}}}{1{,}000}$$

Table 5-3. Estimated Operating Hours for Air-Conditioners

Climate Zone	Hours of Operation Per Year
1	800
2	1,100
3 & 4	1,400
5, 6, & 7	1,700

b. Energy savings (kWh/year) = kW demand for each A/C x number of hours that they could be turned off per year. Sum the kWh savings for all units to determine the total energy savings.

c. Energy cost savings/year = Energy savings (kWh/year) x $/kWh.

d. Capital cost ($) = The installation and equipment cost for a 7-day time clock should not be more than $375 per time clock.

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C-2. REPLACE INEFFICIENT WINDOW AIR-CONDITIONERS

The replacement of window A/C units with more efficient units can cut electrical use for cooling 25 percent or more. The average full-load estimated hours of operation per year for air-conditioners are shown in table 5-3 (option C-1).

a. Preliminary data collection

- Determine the number of existing A/C units. Record their voltage, amperage, and phase ratings from the nameplate of each unit.
- Estimate annual hours of A/C operation (see table 5-3).
- Estimate the cost of an energy-efficient and a standard window A/C unit by calling your local distributor. Additionally ask the distributor to give you the nameplate information for the more efficient unit.
- The kW demand of each unit is given by:

$$kW = \frac{\text{Volts} \times \text{Amps} \times (\text{Phase})^{\frac{1}{2}}}{1{,}000}$$

b. Energy savings (kWh/year)

- If the replacement A/C unit information is known: Energy savings = kW demand (standard unit) - kW demand (energy efficient unit) x number of hours of operation per year for the particular zone.
- If the replacement A/C unit information is not known: Energy savings = kW demand (standard unit) x number of hours of operation per year for the particular zone x 0.25.

c. Energy cost savings/year = Energy savings (kWh/year) x $/kWh.

d. Capital cost ($) - A window A/C unit supplier can furnish the cost and energy use data for the sizes needed. To be sure that they are more energy-efficient than the models that they are replacing, check and compare the energy use (volts x amps) of the old and new units for the same Btu output.

C-3. INSTALL TEMPERATURE CONTROLLER AND SENSOR TO CONTROL CHILLED WATER TEMPERATURE

For a central air-conditioning chiller (centrifugal or absorption), the installation of a controller and sensor to increase the chilled water temperature to the maximum level to maintain proper air temperatures can save energy. Its automatic operation is dependent on outside temperatures and is most effective at saving energy on days when loads on the equipment are low. For example, if the chilled water outlet temperature is 45°F, increasing it to 50°F can save energy.

The design temperature differential between the chilled water supply and the chilled water return is 10° in most cases. If the operating temperature differential is less than 10°, the operating outlet temperature can be changed and the savings calculated.

a. Preliminary data collection.

- Check the chilled water supply and return water temperatures to determine the operating differential.
- Check the chiller nameplate to determine the kW (electrical unit) or pounds of steam per tonnage and tonnage rating (absorption). Contact the chiller manufacturer to determine if the particular chiller can be fitted with a controller.
- Measure or estimate the total steam supply heating efficiency factor (HEF) (for absorption units) (see table B-3, appendix B).
- Estimate the annual hours of operation (see table 5-11, option C-1).

b. Energy savings (kWh/Year or MBtu/Year) - The energy that can be saved is 2 to 8 percent of that used for cooling (2 percent for each degree Fahrenheit that the supply temperature can be raised). The energy saved per unit would be:

- For an electrically driven chiller:

  Energy savings (kWh/year) = Chiller motor kW rating x hours of operation per year x 0.02/°F x increase in water supply temperature (°F)

- For an absorption unit:

  Energy savings (MBtu/year) = Number of pounds of steam used per ton of cooling capacity (usually 20 lbs) x tonnage rating x 970 Btu/lb. x hours of operation per year x 0.02/°F x $\frac{\text{increase in water supply temperature}}{\text{HEF} \times 10^{6}}$

c. Energy cost savings/year = Energy savings (kWh/year or MBtu/year) x \$/kWh or \$/MBtu.

d. Capital cost (\$) = The manufacturer will be able to supply information on the performance and cost of such equipment. An HVAC contractor could also supply this information. Controller requirements will vary with equipment specifications. However, as a starting point it can be assumed that a single point controller should not exceed \$3,500 installed.

C-4. INSTALL ECONOMIZER CYCLE

An economizer cycle will allow the outside air and inside air to mix in the proper proportions so that the least amount of energy is expended to get the air delivered by the air handling units tempered to the required conditions. The economizer cycle is provided by automatic dampers in the air ducts controlled by sensors that monitor air temperature and humidity. When the outside air conditions (temperature and humidity) are similar to the conditions required for delivery from the air handling unit, it is desirable to have this air introduced into the building. If the outside air conditions do not closely match the inside requirements, it is desirable to introduce the smallest amount of outside air required by law. This option is used for central air distribution systems and not for individual fan-coil units located in the outside walls of some buildings. The economizer cycle can reduce the energy used for cooling by about 18 percent.

a. Preliminary data collection.

- o Check the air intake system(s) for the building to see if any dampers are installed. Also, look for return vents to see if air is returned to the heating or cooling units.
- o Locate the chiller nameplate. Determine the kW rating for an absorption unit.
- o Determine the estimated full-load hours from table 5-3 (option C-1).
- o Measure or estimate the steam supply system efficiency (HEF) (for absorption units) (see table B-3, appendix B).

b. Energy savings (kWh/Year or MBtu/year) - The approximate number of MBtu or kWh used for cooling must be known to calculate an energy savings for this option. If the information is unavailable, a conservative estimate can be produced by the following computation:

- o Savings for an electrical unit = kW rating x number of full-load hours x 0.18.
- o Savings for an absorption unit = 20,000 Btu/ton x tons capacity x $\frac{\text{number of full-load hours}}{\text{HEF} \times 10^6}$ x 0.18.

c. Energy cost savings/year = Energy savings (kWh/year or MBtu/year) x \$/kWh or \$/MBtu.

d. Capital Cost (\$) - The cost of an automatic system will vary greatly, depending upon the system chosen. An HVAC contractor or a company that supplies HVAC controls can provide cost information. Most economizer installations will have a cost range of \$2,000 to \$3,000 per system.

C-5. REDUCE SOLAR GAINS THROUGH WINDOWS WITH SOLAR CONTROL DEVICES

Several solar control devices are available which can be installed outside the window, inside the window, or on the window surface itself, to reduce solar gain. They decrease cooling energy use, but increase heating energy use. External sun screens which prevent direct sunlight from falling upon the glass surface are the most effective method of controlling solar heat gain. Internal shading devices are less effective, because once sunlight has entered the building, only a portion can be reflected back through the window.

External shading may be achieved by fitting eyebrows or awnings over the tops of the windows, or fins at the sides of windows. The size and position of these must be determined for each individual case, based on the sun's altitude and azimuth for that particular location. Eyebrows and awnings are most effective over windows with a southern orientation and can be designed to provide total shading from high altitude sun during the middle of the day. Vertical side fins are most effective for east and west orientations.

Methods of installing external sun screens must conform to building codes for fire access and, in certain areas, may be subject to architectural review or approval by arts commissions or historic preservation groups. Elements protruding from the building facade may violate zoning set-back requirements.

External louvered sun screens may be fitted close to the outside surface of the windows and, where possible, within the window frame itself. Operable glazing may permit installation of external sun screens without the use of special staging. The louvered sun screens may be fixed permanently in position or may be arranged to slide in channels, or made removable to take advantage of the sun's beneficial heating effect in winter.

Tinted or reflective glass may be used in addition to the existing glass to convert it from single to double glazing, or may be used to replace the existing glazing. New glazing must be or adequate strength and thickness to meet fire rating and security requirements. Reflective polyester films may be applied directly to the inside surface of the glass. These films are self-adhesive and require careful application to avoid bubbles of trapped air or formation of Newton rings. The film is easily abraded, which reduces performance and appearance. Film on the inside of the building, subjected to inmate wear and tear, will have a reduced useful life. If double glazing is used, apply the film to the inner surface of the outer layer of glass.

Internal shades of various types, e.g., venetian blinds, roller shades, drapes, etc., may be fitted to the inside of the windows. If drapes are used, they should be fire resistant and preferably of woven fiberglass with an aluminum backing which has a higher reflectance. Although internal shades are not as effective as other methods of solar control, they are inexpensive and are easily adjustable. Shades need only be drawn when excessive solar gains are present, and at other times can be opened to allow full view through the window and maximum use of natural light. Insulated shades and drapes are also available, and they reduce heat gains at night. They can be obtained with insulating factors up to R-9. Nocturnal heat gain in summer and winter heat

loss savings should be taken into account in the calculation of total energy savings for internal shades. Normally, for areas where solar controls will be cost effective, the heating capability lost is much smaller and less costly than the cooling energy saved, and can be neglected (see ECO A-7, Thermal Barriers).

a. Preliminary data collection

- Measure the area of all walls and windows and record this total separately for each wall orientation.
- If the windows are poorly sealed, an analysis of the reduction in infiltration should be made for these windows using the procedure delineated in the section on weather stripping. This savings, but not the investment cost of weatherstripping, should be added to the savings total below.
- Determine the latitude of the building, annual mean solar radiation (langleys) and annual degree hours greater than 78°F (dry bulb) from figures 5-15 (Option A-3) and 5-10.
- Identify the orientation of each window where solar control devices may be added.
- Measure or estimate the total cooling system efficiency factor (CEF) (see appendix B, table B-3).

b. Energy savings MBtu/year) - To determine the energy saved by shading devices, use the following procedure:

- Select from figure 5-11 or 5-12 the appropriate graph for latitude, and, entering the graph at degree hours, follow the direction of the example line to intersect with the appropriate langleys and orientation.
- Read out the Annual Heat Gain from the left axis. This gain is for 1 square foot of window, for occupancy of 5 days/week, 12 hours/day. Modify this annual gain as appropriate if occupied time is different. For prison dormitories multiply by 1.4.
- Multiply the Annual Heat gain by the shading coefficient (from table 5-4) of the selected window treatment to obtain the annual reduced solar gain. Reduced Solar Gain = Annual Heat Gain (from figure 5-11 or 5-12) x Shading coefficient (table 5-4).

  Energy savings (MBtu/year) = (Annual Heat Gain - reduced solar gain) x window area (ft^2) $\div 10^3$.

Table 5-4. Shading Coefficients

Glass	
1/8" Clear Double Strength	1.00
1/4" Clear Plate	0.93 - 0.95
1/4" Heat Absorbing Plate	0.65 - 0.70
1/4" Reflective Plate	0.23 - 0.56
1/4" Laminated Reflective	0.28 - 0.42
1" Clear Insulating Plate	0.80 - 0.83
1" Heat Absorbing Insulating Plate	0.43 - 0.45
1" Reflective Insulating Plate	0.13 - 0.31

Shading Device	With 1/4" Clear Plate Glass	With 1" Clear Insulating Glass
Venetian Blinds - Light Colored, Fully Closed	0.55	0.51
Roller Shade - Light Colored, Translucent, Fully Drawn	0.39	0.37
Drapes - Semi-Open Weave, Average Fabric Transmittance and Reflectance, Fully Closed	0.55	0.48
Reflective Polyester Film	0.24	0.20
Louvered Sun Screens		
- 23 Louvers/In.	0.15 - 0.35	0.10 - 0.29
- 17 Louvers/In.	0.18 - 0.51	0.12 - 0.45

Order of Magnitude Costs

Solar Control Device	Average Installed Cost * Per Square Foot
External Louvered Screens	$7.15
Tinted or Reflective Glass	6.00
Reflective Polyester Film	1.70
Venetian Blinds	1.75
Vertical Louvered Blinds	2.40
Roller Shades	2.15

*Edited to reflect 1979 costs.

- o Repeat this procedure for other orientations. Interpolate for orientations other than the four cardinal points. The total energy savings equals the sum of the savings for all orientations.

c. Energy cost savings/year

- o For electrically driven chillers:

  Energy cost savings ($/year) = $/kWh x energy savings ($^{kWh}/_{year}$) ÷ CEF.

- o For absorption units:

  Energy cost savings ($/year) = $^{\$}/_{MBtu}$ x Energy savings ($^{kWh}/_{year}$) ÷ CEF.

d. Capital cost ($). See table 5-4 for the order of magnitude cost.

  Capital cost = window area (ft^2) x order of magnitude cost ($\$/ft^2$).

Figure 5-10. Annual Degree Hours Dry Bulb > 78° F

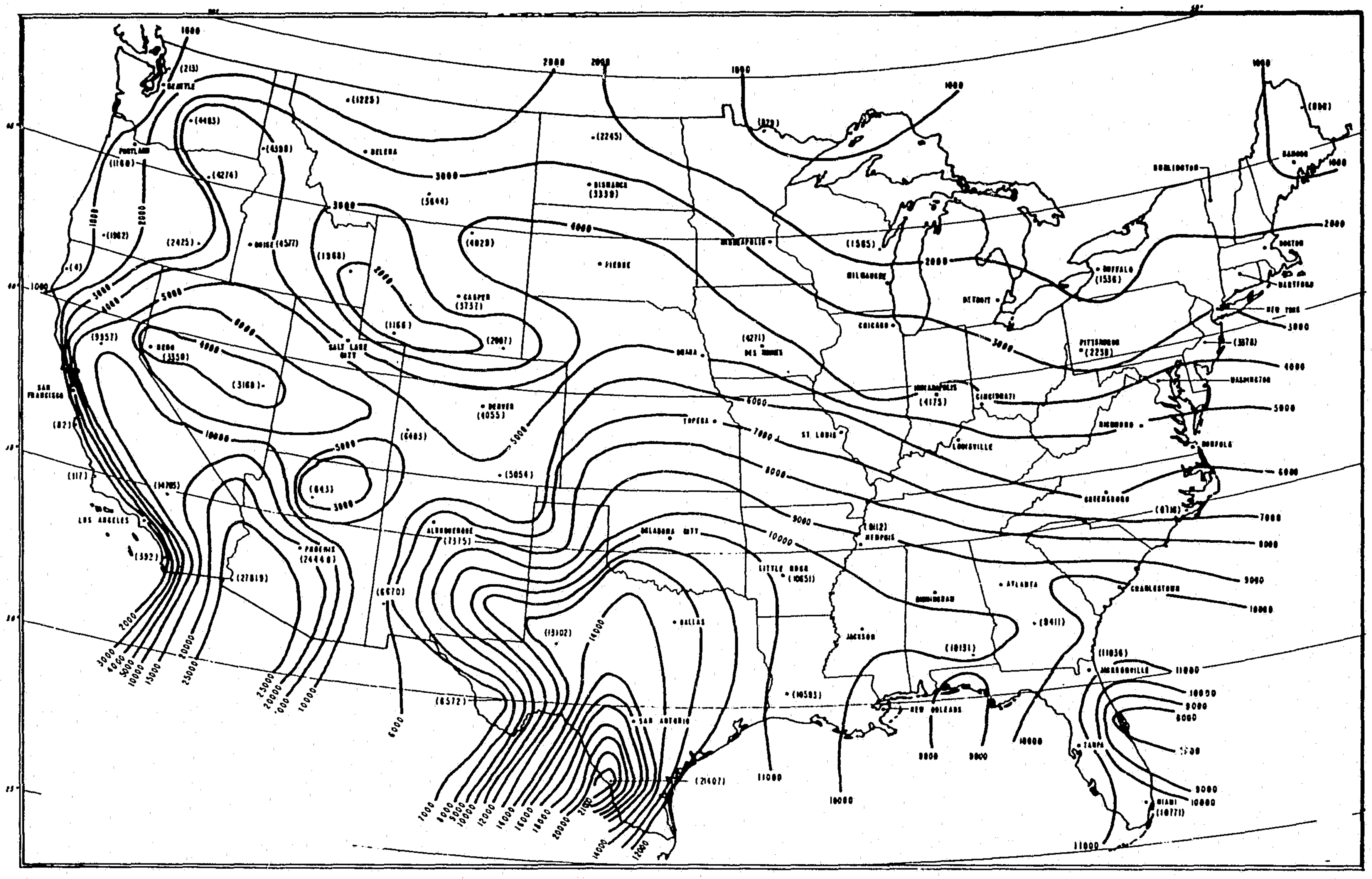


Figure 5-11. Annual Solar Heat Gain Through Windows
Latitude 25° N - 35° N

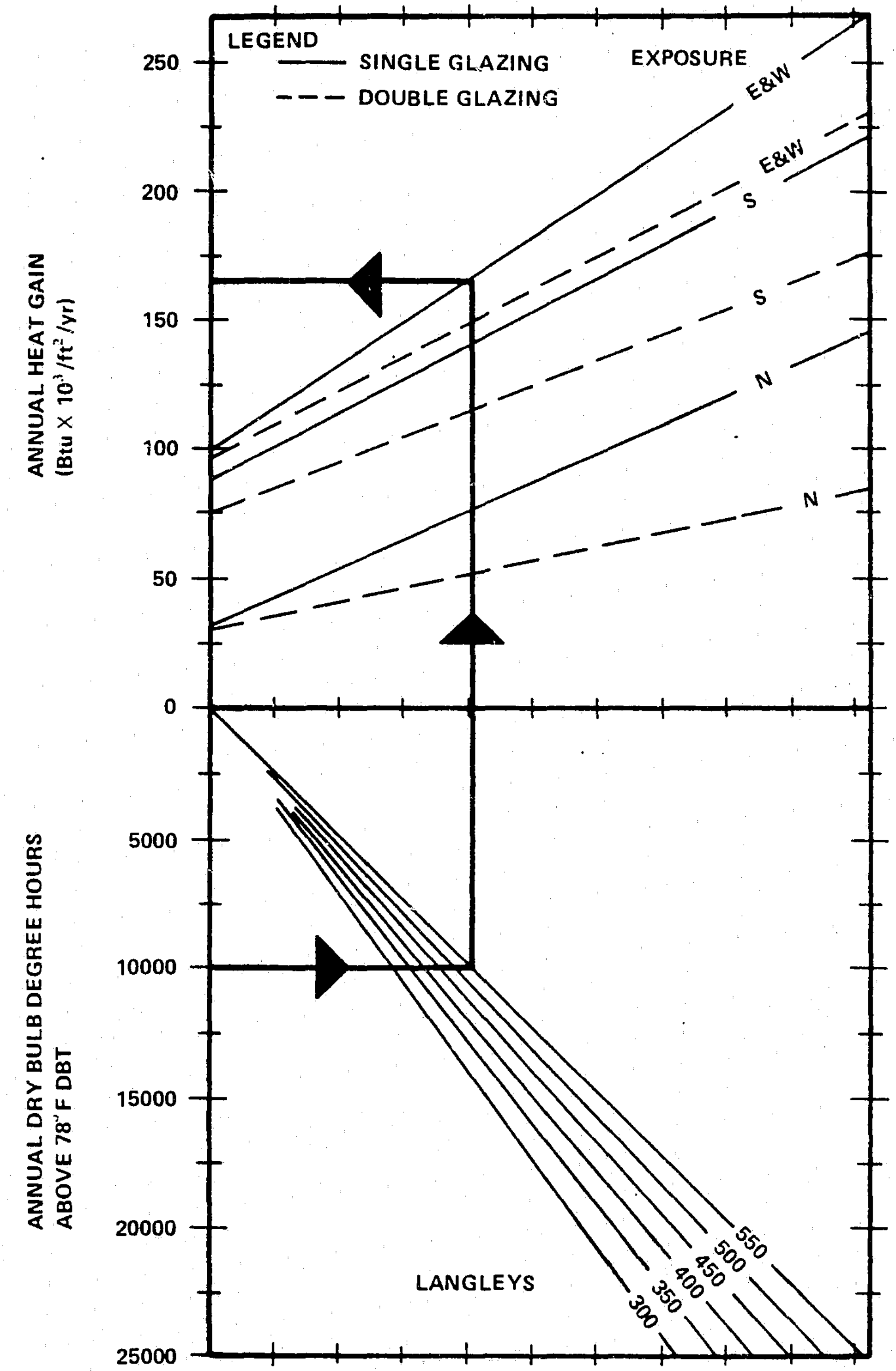
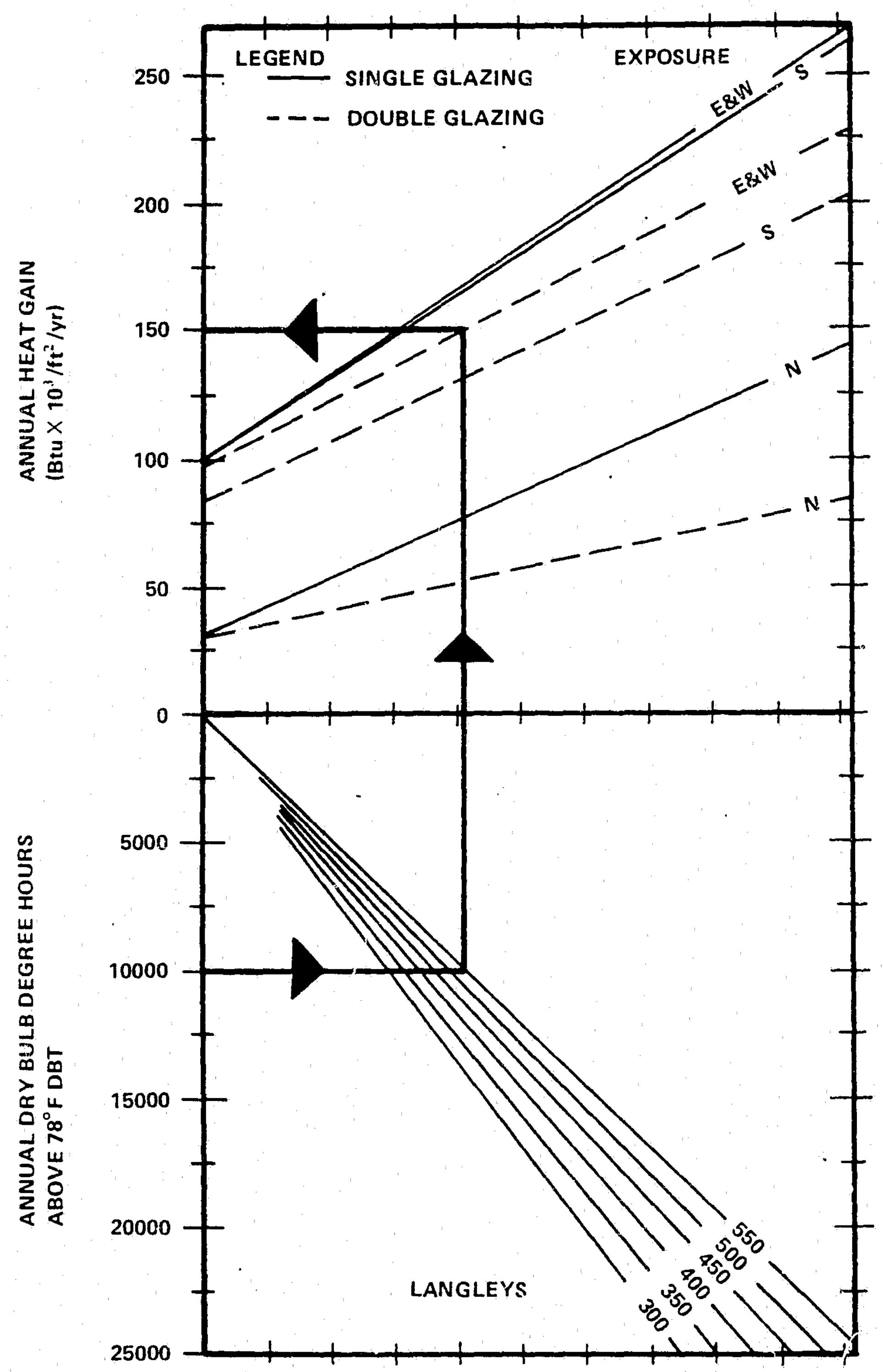


Figure 5-12. Annual Solar Heat Gain Through Windows
Latitude 35° N - 45° N



LIGHTING OPTIONS

L-1. REMOVE LAMPS OR FIXTURES

L-2. USE ENERGY CONSERVING FLUORESCENT LAMPS

L-3. CONTROL EXTERIOR LIGHTING

L-4. USE MORE EFFICIENT LIGHTING SOURCES

L-5. INSTALL SWITCHING

4. LIGHTING OPTIONS (L)

The efficiencies of lighting systems are affected by types of fixtures and lamps; wall, floor, and ceiling colors; and lamp and fixture maintenance. The effective light can be increased without using more energy by using efficient lighting sources, making sure that the room has light-colored walls, and by periodically cleaning the lamps and fixtures.

If a light meter is available, measurement of the light levels for an area can be make quickly and easily. General recommendations for light levels are identified in table 5-5.

In order to determine how much light is being supplied by a particular lighting system, a watts/square foot method can be used if no light-measuring device is available. The number of watts can be totaled for each area and divided by the square footage. Generally, if the watts/square foot average is over 3.00 then a reduction in lighting is possible. Although this is the level generally recommended for working conditions, it is equally applicable to prisons. Visibility of resident activities does not improve significantly under higher lighting levels, but it does increase energy use. A goal of an average 2.3 watts per square foot is achievable for most prison working and reading areas. This roughly equates to three watts per square foot working or reading areas, two watts per square foot in adjacent circulation areas, and one watt per square foot in corridors and other nonworking areas. These general guidelines and table 5-5 will assist in determining adequate lighting for the security of staff and residents. As in other options, the effect of implementing one option may affect the calculation for additional options. The following section contains retrofit options for lighting systems.

Table 5-5. Recommended Lighting Levels

Task or Area	Design Level (Footcandles)	Average Level Range (Footcandles)
Service or public area	15	12 - 18
Circulation areas within office space, but not at work stations	30	24 - 36
Normal office work, reading, writing, etc.	50	40 - 60
Office work, prolonged, visually difficult or critical in nature	75	60 - 90
Auditorium	30	20 - 40
Cateteria	30	20 - 40
Conference rooms	30	25 - 35
Corridor, lobby and means of egress	15	10 - 18
Kitchen (average)	50	30 - 70
Mechanical room (general area)	10	5 - 15
Storage area (general storage)	10	25 - 35
Storage area (fine details required)	30	25 - 35
Toilets	20	15 - 30
Welding*	50	
Woodworking*		
o Rough sawing & bench work	10	
o Sizing, planing, rough sanding, medium quality machine and bench work	50	
o Fine bench and machine work, fine sanding and finishing	100	

*From American National Standard Practice for Industrial Lighting, ANSI/IES RP-7, 1979

Note: These are only recommended values. There is no conclusive data about how much light is really needed for someone to perform a specific task.

L-1. REMOVE LAMPS OR FIXTURES

Lighting levels are measured in footcandles (fc). Lighting level recommendations are given in footcandles, and are dependent upon the difficulty of the visual work to be done. The more difficult the visual task, the more light (in footcandles) is required to perform that task. However, if a space has a footcandle level above the recommended lighting level, energy can be saved without decreasing worker performance by reducing the lighting level to within a recommended range. The recommended levels for this handbook are from the Illumination Engineering Society (IES) and are shown in table 5-5.

Lamps and fixtures in areas where people are working should not be arbitrarily removed. It is recommended that qualified prison or jail personnel supervise the removal of lamps and/or fixtures in work areas. In areas where people are not working, such as corridors, dining areas, etc., the quantity of light becomes less critical, and reduced lighting levels easier to accomplish. Lighting must not be diminished to levels that provide potentially dangerous conditions for both prison guards and residents.

When delamping fluorescent and high intensity discharge (H.I.D.) fixtures, it is important to disconnect the associated ballasts. A ballast usually serves two lamps in a fluorescent fixture and one lamp in an H.I.D. fixture. If the ballast is not disconnected, it will continue to draw power (approximately 10-15 percent of the lamp wattage). Another reason to disconnect ballasts when delamping is to prohibit the light fixture from mistakenly being relamped.

a. Preliminary Data Collection

- Measure lighting levels using a footcandle meter. For the specific task performed in the space, the measured light level should fall within the recommended range shown in table 5-5.
- Decide how many light fixtures or lamps can be removed from the space to achieve the desired lighting level. Determine the number of watts per lamp for each type of lamp removed.
- For fluorescent lamps, the watts saved per lamp is given in table 5-6.
- Determine the operating hours of the lighting system.

Table 5-6. Watts Saved By Lamp And Ballast Removal

Type of Fluorescent Lamp Removed	Watts Saved Per Lamp Removed	Watts Saved Per Ballast Disconnected
4' energy conserving (35 watt)	35	4
4' standard (F40CW)	40	6
4' high output	60	12
8' energy conserving	60	10
8' standard (F96T12)	75	10
8' energy conserv. high output	90	5
8' high output	100	5

b. Energy savings (kWh/year) = Number of lamps removed x watts/lamp x hours of operation per year ÷ 1,000.

c. Energy cost savings/year = Energy savings (kWh/year) x $/kWh.

d. Capital Cost ($) - The cost to disconnect or remove fixtures depends on the labor rate for a particular location. Generally, it will cost $5 to $10 to remove a lamp and disconnect ballast, and $10 to $20 to completely disconnect and remove the fixture. If staff or inmate labor is not available at the facilities, then an electrical contractor can supply the cost estimate.

L-2. USE ENERGY-CONSERVING FLUORESCENT LAMPS

It is possible to save 15 to 20 percent of the energy used by a 4' fluorescent lamp by relamping with 35W lamps instead of standard 40W lamps. There are two types of 35W fluorescent lamps. The first generation is a standard cool white color and produces approximately 10 percent less light output (lumens) than the standard 40W lamp. The second generation 35W lamp is a blend of new phosphors which gives a different color of light than the cool white lamp. The color of light produced by the newest 35W lamp is called Lite White.

The advantage of the new Lite White lamp is that it produces approximately the same light output as the standard lamp, while using less energy. (See table 5-7 for lamp performance characteristics.) The disadvantage is that the Lite White color reduces color rendition compared to the cool white and should not be used where color visibility is critical. (Experiment with sample lamps to determine if the Lite White color is acceptable. In most cases, it should be.)

The disadvantage of both 35W lamps is that they should not be used where ambient temperatures fall below 60°F or where they are exposed to a cold draft. Another consideration is that if the existing ballasts are old, when relamping with new 35W lamps, many of these ballasts may fail and have to be replaced. These ballasts should be replaced with the new energy conserving ballasts.

a. Preliminary data collection

- o Check lamp supplies to determine the type and wattage of lamps presently used in the facility.
- o See table 5-7 for possible retrofit lamps.
- o Determine the number of operating hours/year for each lamp type.
- o Count the fluorescent lamps for each existing lamp type used in the facility.
- o Select the desired retrofit lamp using information found in table 5-7. The primary concerns should be: light output, lamp color, and building ambient temperature.

  Note: Local lamp manufacturer's representatives can answer any questions concerning lamp types, performance, and applicability. Do not hesitate to call for help.

b. Energy savings (kWh/year) = Number of lamps being replaced x (watts/lamp for standard lamps - watts/lamp for replacement lamps) x number of hours per year the lights are on ÷ 1,000.

c. Energy cost savings/year = Energy savings (kWh/yr) x $/kWh.

d. Capital cost ($) = Number of lamps x $/lamp. The exact cost for these lamps can be obtained from manufacturers, suppliers, and contractors.

They will be approximately $3 for a 4' lamp and $4 for an 8' lamp. Typical installed costs would be $6.50 and $7.50, respectively. If it is not feasible or cost-effective to relamp the entire facility, an alternative would be to replace the existing lamps with energy-efficient lamps under the existing lamp maintenance program. If the lamps are replaced as part of the lamp maintenance program, the budget for regular purchase of replacement lamps should be increased by approximately 20¢ per lamp changed.

Table 5-7. Standard and Energy Conserving Fluorescent Lamps

Standard Lamps				Energy-conserving Lamps				
Existing Lamp	Watts	Light Output	Lamp Life	Replacement Lamp	Watts	Light Output	Lamp Life	Comments
1-4 ft. -40W (F40)	46	3,150	20,000	1-4 ft. -35W	39	2,850	20,000	10% reduction in light output.
				1-4 ft. -35W*	39	3,050	20,000	Approx. 3% reduction in light output.
1-8 ft. -Slim**	85	6,300	12,000	1-8 ft. -Slim	70	5,600	12,000	11% reduction in light output.
				1-8 ft. -Slim	70	6,000	12,000	Approx. 5% reduction in light output.
1-8 ft. - HO***	121	9,050	12,000	1-8 ft. HO	105	8,400	12,000	7% reduction in light output.
				1-8 ft. HO	105	8,900	12,000	Approx. 2% reduction in light output.

*Lite White
**Slim Line
***HO = High Output, 800 M.A.

Note: Contact local lamp manufacturer's representatives for more detailed information about the products available.

L-3. CONTROL EXTERIOR LIGHTING

If some exterior lights are not required all night long, energy can be saved by turning them off using a time clock. Time clocks must have a spring backup to cover electrical outages. Astronomic time clocks automatically account for changes in sunset and sunrise and can be set for any particular altitude. As with ordinary time clocks, they must be reset for daylight saving time twice a year. A photocell or time clock can be used individually to turn the lights on and off, or they can be combined, such that the lights are turned on by the photocell as darkness falls, and turned off by the time clock at a predetermined time during the night hours.

a. Preliminary data collection

- o Check the exterior lighting procedures: when lights are turned on, off, and how they are controlled.
- o Determine the number of lights which need to remain on for safety and security, and the number of lights which can be turned off.
- o Identify the number and types of lamps and their wattages.
- o Determine the number of operating hours the lighting system can be turned off.
- o Select a lighting control method (photocell/time clock). Estimate the number of photocell/time clock arrangements required.

b. Energy savings (kWh/year) = Number of lamps turned off x watts/ lamp x number of hours per year turned off ÷ 1,000.

c. Energy cost savings/Year = energy savings (kWh/year) x $/kWh.

d. Capital cost ($). Time clocks with astronomical dial and reserve power can be purchased and installed for approximately $200. A photocell can be purchased and installed for less than $50 per unit.

L-4. USE MORE EFFICIENT LIGHT SOURCES

Three basic types of existing light sources are: (1) incandescent, (2) fluorescent, and (3) high-intensity discharge (H.I.D.). The H.I.D. types consist of three categories: (1) mercury, (2) metal halide, and (3) high-pressure sodium (HPS). To provide a specific quantity of light using the least amount of energy, the most efficient light source appropriate for the task should be used. The sources are shown in table 5-8 in order of their light-producing efficiency, from the lowest to the highest.

For example, it would require 5W of an incandescent light source to provide the same quantity of light produced by just 1W of a HPS light source. Therefore, it is possible to save energy by replacing an existing lamp with a higher-efficiency lamp. A brief description of light source characteristics can be found in table 5-8.

a. Preliminary Data Collection

- Determine areas where higher-efficiency lamps can be used in place of existing lamps.
- Record the number of existing light fixtures, and determine the total wattage of all lamps in the fixture to obtain total watts per fixture. Use the equation in table 5-9 to determine the wattage of the retrofit lamp needed to replace the existing lamps while maintaining approximately the same light output.
- Examine table 5-8 to determine the appropriateness of each source, based upon application and lamp characteristics.
- Determine the retrofit lamp type that is most appropriate for the application, and note its wattage per lamp (from table 5-8).
- Determine the operating hours of the existing systems.

b. Energy savings (kWh) = (Number of existing system fixtures x watts/fixture) - (Number of Retrofit System fixtures x watts/fixture)) x hours of operation/year ÷ 1,000.

c. Energy Cost Savings/year = energy savings (kWh/year) x $/kWh.

d. Capital Cost ($) - For estimating purposes, the installed cost of retrofit fixtures is given in table 5-8. The costs of replacement lamps for the retrofit fixture are given in table 5-10. More accurate costs can be obtained from manufacturers, suppliers, and contractors. Do not hesitate to call for estimates.

Table 5-8. Recommended Retrofit Replacement Lamps

Light Source	Light Output Lumens/Watt	Lamp Life (hrs.)	Typical Uses	Comments	Recommended Retrofit Replacement Lamps: Lamp Type	Recommended Retrofit Replacement Lamps: Fixture Cost
Incandescent	20	1,000	Areas where good color is required. Where possible, replace this source with a more efficient source.	Starts instantly. Good color. Many Wattages available.	See Note A. 1st Fluorescent 2nd H.I.D. See Note B. 1st Metal Halide 2nd HPS	See Note C. $135 $250 $300
Fluorescent (Needs ballast)	68	20,000	Most indoor applications; use carefully outdoors.	Starts instantly. Good color, many colors available.	Do not replace unless more than 15' above floor. 1st MH, 2nd HPS.	
Mercury (needs ballast; many wattages available)	55	24,000	Indoors and outdoors. Other H.I.D.'s are more energy-efficient.	Starting 4-5 min. warm-up. Many colors available. Can get good color.	1st Metal Halide 2nd HPS, if color is acceptable.	$300 $400
Metal Halide (MH) (Needs ballast)	80	15,000	Indoor and outdoors. Hi-bay areas (over 15'), and outdoors.	Starting 5-6 min. warm-up. Good color Many wattages available.	Do not replace unless HPS color is acceptable. Then consider HPS.	
High-Pressure Sodium (HPS) (Needs ballast)	100	24,000	Indoors if color is acceptable. Hi-bay areas (over 15'), and outdoors.	Starting 3-4 min. warm-up. Yellow light may be unacceptable. Many wattages available.	Do not replace unless color unacceptable.	

NOTE A: For fixtures less than 15' from the floor. For outdoor use, H.I.D. is 1st choice.
NOTE B: For fixtures greater than 15' from the floor.
NOTE C: Installed cost (includes design and project management cost)

Table 5-9. Determination of Efficient Lamp Wattage

To find the wattage required for a new, more efficient light source, use the following equation:

$$\text{Wattage per fixture (retrofit)} = \text{wattage per fixture (existing)} \times \frac{\text{lumens/watt (existing lamp)}}{\text{lumens/watt (retrofit lamp)}}$$

Assume the following outputs [lumens per watt (lm/W)]

Incandescent:	20 lumens/watt
Fluorescent:	68 lumens/watt
Mercury:	55 lumens/watt
Metal Halide:	80 lumens/watt
High-Pressure Sodium (HPS):	105 lumens/watt

Example 1: Replace a 300-watt incandescent with:

Fluorescent: wattage of fluorescent lamp required $= 300W \times \frac{20\ lm/W}{68\ lm/W} = 88$ watts

Mercury: wattage of mercury lamp required $= 300W \times \frac{20\ lm/W}{55\ lm/W} = 109$ watts

Metal Halide: wattage of metal halide lamp required $= 300W \times \frac{20\ lm/W}{80\ lm/W} = 75$ watts

HPS: wattage of HPS lamp required $= 300W \times \frac{20\ lm/W}{105\ lm/W} = 57$ watts

Example 2: If the fixture has two 150-watt incandescent lamps, replace this fixture with:

Flourescent: wattage of fluorescent lamp required $= (2 \times 150W) \times \frac{20\ lm/W}{68\ lm/W} = 88$ watts

Mercury: wattage of mercury lamp required $= (2 \times 150W) \times \frac{20\ lm/W}{55\ lm/W} = 109$ watts

Metal Halide: wattage of metal halide lamp required $= (2 \times 150W) \times \frac{20\ lm/W}{80\ lm/W} = 75$ watts

HPS: wattage of HPS lamp required $= (2 \times 150W) \times \frac{20\ lm/W}{105\ lm/W} = 57$ watts

Table 5-10. Lamp Costs

Lamp Type	Approximate Cost
Incandescent	$ 3.00
Fluorescent	3.00
Mercury Vapor	15.00
Metal Halide	37.00
HPS	50.00

L-5. INSTALL SWITCHING

Energy can be saved by installing switches or by arranging for multiple switching of lamps so that lights not regularly in use during occupied or unoccupied hours can be switched off. This also would apply to lighting, located near windows, that can be switched off during daylight hours.

In cases where there are no switches at all and lights must be turned on and off by the circuit breaker, there is effectively little or no control of the lighting system. This condition reduces the life of the breaker, and may also constitute a safety violation.

a. Preliminary data collection

- o Determine what areas could benefit from the addition of switches.
- o Determine the type and number of lamps in identified areas and the number of watts per lamp.
- o Determine the present operating hours of the lights.
- o Determine how many lamps could be turned off and the number of operating hours the lamps could be turned off by installing switching.
- o Estimate the number of switches required.

b. Energy savings (kWh/year) = Number of lamps turned off x number of watts/lamp x hours of operation per year ÷ 1,000.

c. Energy cost savings/year = Energy savings (kWh/year) x $/kWh.

d. Capital cost ($) - An electrical contractor can supply a cost estimate for switching. As an initial estimate, $75 to $125 per switch can be used (includes conduit and wiring).

WATER HEATING OPTIONS

W-1. INSTALL WATER FLOW RESTRICTORS

W-2. INSULATE DOMESTIC HOT WATER TANK

W-3. INSTALL DECENTRALIZED WATER HEATING

W-4. USE WASTE HEAT FOR WATER HEATING

5. WATER HEATING (W)

This section addresses energy conservation in the heating of domestic hot water. Although the percentage of energy used to heat water for domestic use is small for most buildings, it is an area where opportunities for energy savings exist. In inmate housing, hot water usage can be significant when inmates do not shut off faucets or showers. There are several operational methods that can be used to conserve hot water, such as reducing the temperature of the hot water or adjusting the hot water valves to restrict the water flow. The options contained in this section offer additional opportunities, through retrofitting, to conserve energy used for water heating.

Domestic hot water use in prison housing is large enough to justify investigations of the options in this section.

It should be emphasized that water conservation opportunities are an important additional area to reduce utility costs. It is significant to note that 54 percent of the cost of water is in the cost of energy to pump, store, process, distribute, and dispose of water. It is, therefore, important to reduce consumption of cold water, as well as hot water, whenever possible.

W-1. INSTALL WATER FLOW RESTRICTORS

Domestic hot water use can be reduced by approximately 50 percent with the installation of flow restrictors for shower nozzles and water faucets. Flow restrictors reduce the number of gallons of water used per minute. The average daily amount of hot water used per person is:

2 gallons/day/person in administration

15 gallons/day/person in resident housing

40 gallons/day/person in hospitals and infirmaries

The savings in total water use, both hot and cold, will be about 50 percent of the total present water use. The present value of the water cost savings could be added to the present value of the energy cost savings to estimate the full cost reduction.

a. <u>Preliminary data collection</u>

- o Determine the number of sinks and showers where flow restrictors could be installed.
- o Identify the building use and determine the gallons/day/person (gdp) from the above estimates.
- o Determine the average number of occupants of the building, the number of days of building is occupied per year, and the domestic hot water temperature.
- o Measure or estimate the water heating system efficiency (WEF). (See appendix B, table B-3).

b. <u>Energy savings (MBtu/year)</u> = Number of occupants x gallons/day/occupant x occupied days/year x 600 Btu/gallon x 0.5 x

$$\frac{\text{present domestic hot water temperature (°F)}}{130°\text{F} \times 10^6 \times \text{WEF}}$$

c. <u>Energy cost savings/year</u> = Energy savings (MBtu/year) x $/MBtu. An additional cost savings can be added to this calculation to account for the reduced water and sewer charges that will result from the decreased use of water.

d. <u>Capital cost ($)</u> - The cost to purchase and install valve-type flow restrictors will most likely be less than $10 per unit if the entire faucet or shower head is changed. The cost to purchase and install washer-type flow restrictors will most likely be $2.00 - $3.00 per unit.

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W-2. INSULATE HOT WATER STORAGE TANK

The loss of heat from domestic hot water storage tanks must be continuously offset by the addition of heat to maintain a ready supply of hot water. This heat loss occurs 24 hours a day, whether the building is occupied or not. Storage tanks should be covered with insulation having a minimum conductivity of 0.3. Insulate bare tanks and apply additional insulation to tanks having less than three inches of insulation. Replace or repair all missing or torn insulation as required. Applicable codes should, of course, be checked to determine the acceptability of various insulation materials. Obtain quotations for accurate cost assessment.

Calculate the savings form this retrofit option by comparing the heat loss from the tank before and after insulation (assume that water temperature and ambient air temperature are constant). To assist in these calculations, table 5-11 indicates the annual energy loss in MBtu for various sizes of tanks located in a space with an ambient air temperature of 65°F, with an insulation thickness as indicated.

a. Preliminary data collection

- o Determine tank size from building mechanical drawings or from the nameplate data on the tank.
- o Check the tank to determine the thickness of existing insulation, if any.
- o Measure or estimate the hot water temperature.
- o Identify the thickness of the new insulation to be applied.
- o Measure or estimate the water heating system efficiency factor (WEF).

b. Energy savings (MBtu/year) = [Heat loss with existing insulation (MBtu/year) - Heat lost with new insulation (MBtu/year)] ÷ WEF.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($). Quotations must be obtained to provide an accurate cost estimate. As a rough estimate, the purchase and installation of 3" of insulation will cost from $1.00 - $2.00 per gallon of storage capacity.

Table 5-11. Insulation Thickness and Tank Size Related to Yearly Heat Loss

Insulation	Tank Size in Gallons	MBtu/Year Lost at Water Temperature °F		
		100°F	140°F	180°F
Bare	50	11.4	26.5	44.7
	100	19.2	44.6	75.2
	250	33.6	78.2	131.8
	500	55.1	128.1	216
1"	50	1.8	3.0	5.9
	100	3.0	6.5	10.0
	250	5.3	11.4	17.5
	500	8.7	18.7	28.7
2"	50	1.0	2.1	3.2
	100	1.6	3.5	5.3
	250	2.8	6.1	9.4
	500	4.6	10.0	15.3
3"	50	0.6	1.4	2.1
	100	1.1	2.4	3.6
	250	1.9	4.1	6.3
	500	3.1	6.8	10.4

Note: Assumes 8760 hours of operation per year (continuous) and an ambient air temperature of 65°F.

W-3. INSTALL DECENTRALIZED WATER HEATING

If domestic hot water is supplied by a central system that supplies both heating and domestic water, and that can be shut down during warm months, the installation of small, decentralized units close to the area in which the hot water is used can save energy and money. This is especially true if a large boiler must be run in warm months just to supply hot water.

If a large boiler is being operated below 20 percent of its full-load capacity just to supply hot water, the, as a rule, the amount of fuel used to generate that hot water could be cut by 50 percent through the installation of a smaller, more efficient unit just for hot water.

a. Preliminary data collection

- o Check to see if the central boiler supplies hot water or if there is a separate unit for hot water supply. If it is from the central system, the boiler operating personnel will know whether the system is operating below 20 percent of capacity during warmer months.
- o Determine the number of days per year that the central boiler is used for water heating only (see table 5-1, option H-1).
- o Since the savings from installing a decentralized water heater depend on the function of the building and the number of people served by the system, determine the occupancy of the building or buildings served by the central system.

b. Energy savings (MBtu/year) = Number of gallons used/day/person* x number of people x number of days/year that the central boiler is used for hot water heating only x 600 Btu/gallon x 0.5 x $\frac{\text{present hot water temp (°F)}}{130\text{°F} \times 10^6}$.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital costs ($) - The cost of units specifically designed for water heating range from $4 to $10 per gallon of installed capacity for domestic-type units, to $5 to $15 or greater for larger commercial units. A mechanical contractor or equipment manufacturer can provide more accurate estimates.

*See retrofit option W-1 for average number of gallons used per person.

W-4 USE WASTE HEAT FOR WATER HEATING

Waste heat from flue gases, from a boiler that operates year-round can be recovered by using a heat exchanger. The heat exchanger can then be used to heat water for domestic use that would otherwise have to be heated directly by the boiler or a water heater. Some engineering assistance is needed to evaluate the feasibility of the option. The investment cost of the equipment needed for this retrofit option depends entirely upon the specific system required. However, it is not uncommon for the heat recovered from the boiler flue gas to be sufficient to supply the domestic hot water needs for the building or group of buildings served by the boiler. Care should be taken so that the flue gas temperature is not reduced to the point (below 350°F or 250°F for natural gas) that condensation of an acidic nature is produced in the stack. This can cause damage to the equipment.

The option should be pursued if heat is not already being recovered from the flue gas (see options H-5 and H-8).

a. Preliminary data collection

- o Estimate the number of gallons of domestic hot water needed/year based on building occupancy. (See retrofit option W-1 for average number of gallons used per person).
- o Measure or estimate the domestic hot water system energy efficiency (WEF). (See appendix B, table B-3).
- o Determine the domestic hot water temperature.

b. Energy savings (MBtu/Year) = Number of gallons used for water heat/year x 600 Btu/gallon x $\frac{\text{present hot water temp (°F)}}{130\text{°F} \times \text{WEF} \times 10^6}$.

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - This cost should be obtained from the manufacturers of commercially available heat exchangers. Costs will vary greatly for each different type of boiler system, boiler fuel and the amount of hot water needed.

ARCHITECTURAL OPTIONS

A-1. INSTALL CAULKING

A-2. INSTALL WEATHERSTRIPPING

A-3.1 INSTALL WALL INSULATION

A-3.2 INSTALL ROOF INSULATION

A-4. INSTALL STORM WINDOWS

A-5. INSTALL THERMAL BARRIERS

A-6. INSTALL LOADING DOCK DOOR SEALS

A-7. INSTALL VESTIBULES

6. ARCHITECTURAL OPTIONS (A)

The options in this section include retrofit opportunities to improve various aspects of the building envelope. In some single-story buildings, the energy conservation effort, through retrofitting, is best devoted to the energy use system within the building. Frequently, however, the construction of the building adds greatly to the energy requirements within. The factors which influence the energy use as related to the building envelope include: (1) the type of construction; (2) the amount, if any, of insulation; (3) the amount of window area; (4) the building size; and (5) the age and upkeep of the building exterior.

A-1. CAULK ALL GAPS IN EXTERIOR SURFACES

Caulking helps prevent energy loss in buildings. For example, as much as 40 percent of the energy loss in small structures is due to infiltration, and it is estimated that 20 percent or more - or half the total loss through infiltration- is due to poor (or lack of) caulking. Because caulking is relatively inexpensive to purchase and install, this option is normally a cost-effective conservation opportunity.

There are many caulking compounds, including butyl, latex, and silicone, with prices ranging from less than $1 to as much as $8 per tube. The lifetime of most caulk is limited. Most caulk will have to be replaced with fresh caulk within 5 years of application. An exception is silicone caulk, which can be expected to last the life of the building if properly applied. The cost of silicone caulk ranges from $6 to $8 per tube, or about 6 cents per foot of 1/4" caulkbead. It is recommended that silicone caulk be used for all caulking. The following costs are calculated on this basis.

a. Preliminary data collection

- Note the lengths of cracks found, and the type of material on the exterior surfaces of the building, if it will influence the type of caulk to be used. Assume a 1/4" crack width if unknown.
- Determine the heating or cooling degree days (HDD or CDD) for your area. (See figure 5-13 or 5-14).
- From weather records, National Weather Service, or other source, determine your average wind velocity in miles per hour or assume 10 mph.
- Measure or estimate your total heating or cooling system fuel efficiency factor, HEF or CEF. (See appendix B, table B-3).
- From table 5-12, determine infiltration in cubic feet of air per hour per foot of crack.

b. Energy savings (MBtu/year*) = Infiltration, in $ft^3/hr/ft$ x number of feet of crack x $\frac{0.434\ (Btu/ft^3/day) \times HDD}{HEF \times 10^6}$ x length of heating season (hours).

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($). The cost of caulking with silicone caulk should not exceed $0.06 per linear foot.

*If cooling is employed, repeat the calculations for cooling energy savings. Sum the heating and cooling energy systems savings to obtain the total energy savings.

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Figure 5-13. Annual Heating Degree Days

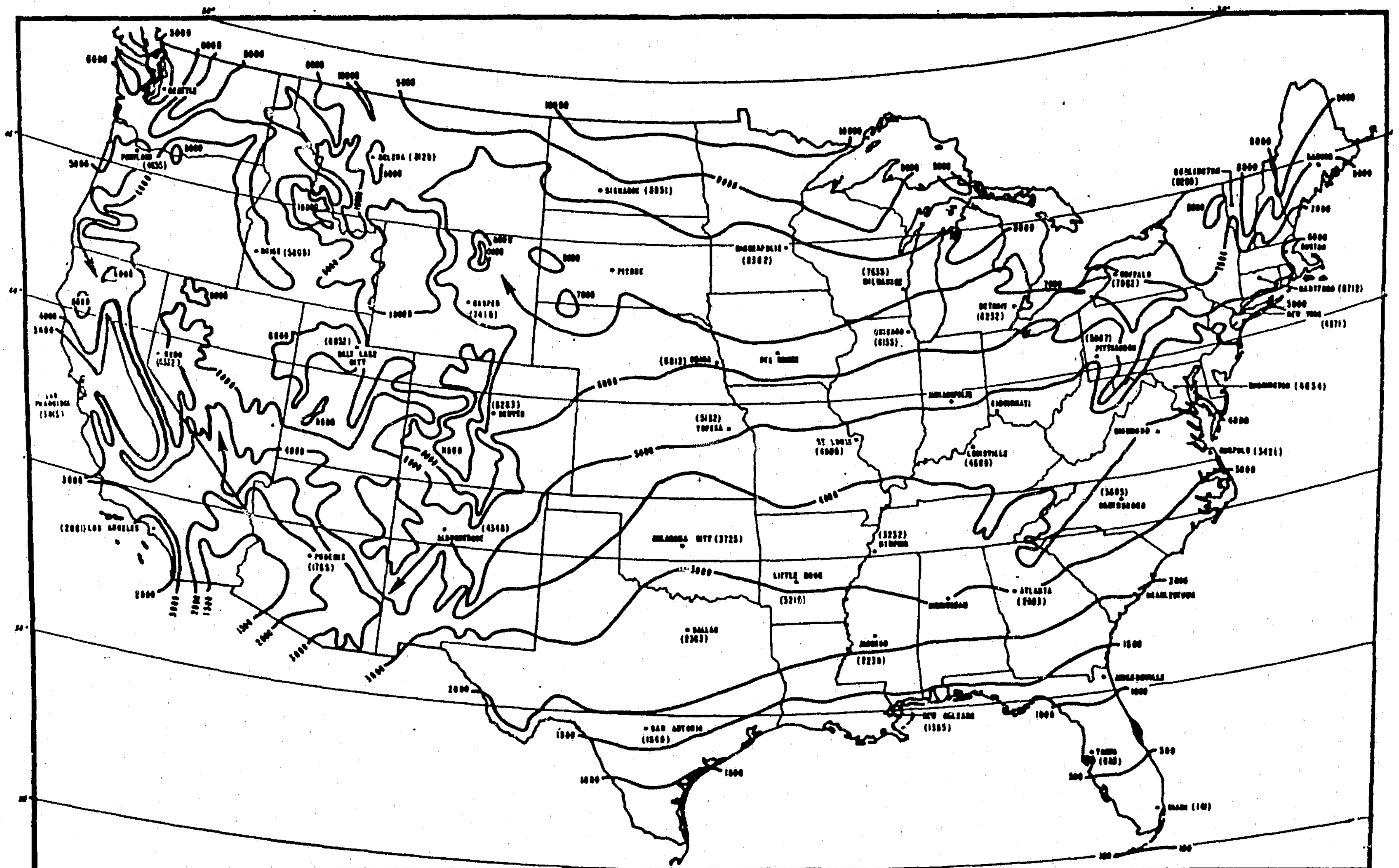

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Figure 5-14. Annual Cooling Degree Days

Table 5-12. Infiltration In Cubic Feet Per Hour Per Linear Foot Of Gap

	WIND SPEED (MILES PER HOUR)				
Gap Width, Inches	10	15	20	25	30
1/16	19	31	41	49	57
1/8	27	43	57	69	80
1/4	38	60	80	97	113
1/2	53	85	113	136	158
1	75	120	159	192	222
1-1/2	90	144	191	231	267
2	105	169	224	270	312
2-1/2	126	203	270	325	375
3	148	238	316	381	439

A-2. WEATHERSTRIP WINDOWS AND DOORS

As much as 20 percent of the energy used in a typical residence or small building is lost as a result of air infiltrating through poorly weatherstripped windows and doors. Weatherstripping window and door seals can yield large energy savings at low investment costs. The service life of weatherstripping is estimated at approximately 5 years.

a. Preliminary data collection

- o Examine all window and external door seals. If more than 1/16" gap is detected, the door or window should be weatherstripped.
- o Record the length and width of the gap.
- o Determine the heating or cooling degree days (HDD or CDD) for your area.* (See figure 5-13 and 5-14).
- o Contact the National Weather Service to determine the average wind velocity for your area or assume an average speed of 10 mph.
- o Measure or estimate the total heating or cooling system efficiency factor, (HEF or CEF). (See appendix B, table B-3).
- o From table 5-12, determine infiltration in cubic feet of air per foot of crack.

b. Energy savings (MBtu/year)* = Infiltration, in cubic feet per hour/ft x linear feet of gap x $\frac{0.434 \text{ Btu/cubic ft./day} \times \text{HDD}}{\text{HEF} \times 10^6}$ x length of season (hrs.).

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - The cost for weatherstripping should not exceed $1.80 per linear foot (including labor).

*If cooling is employed, repeat the calculations for cooling energy savings. Sum the heating and cooling energy savings to obtain the total energy savings.

A-3. BUILDING INSULATION

The insulating character of an exterior surface will determine the amount of heat which is either gained or lost to the ambient air. The addition of insulation will increase the resistance of the surface to heat transfer, and save energy. Heating fuel savings would be realized during heating months while reduced cooling load requirements would occur in the cooling months. Insulation will generally be most cost-effective in roofs or attics followed in order by north walls, crawl spaces, east walls, west walls, south walls, below-grade basement walls, slab on grade floors, and basement floors.

Retrofit options A-3.1 (Insulate Roofs) and A-3.2 (Insulate Walls) present the most likely opportunities to save energy in prisons. In addition, since heating energy costs are a large portion of a prison's total energy cost throughout most of the United States, the method for calculating energy savings only accounts for heat losses. The contribution to the cooling load by summer heat gain is not addressed in either option.

Building insulations may be broadly categorized into three groups: (1) rigid, (2) nonrigid, (3) expanded or blown. Rigid insulation is a prefabricated board or panel. Nonrigid insulating materials include batts or blankets of loosely bonded fibers with a paper or foil backing. Expanded or blown insulations are foams or sprays which conform to the interior of cavities.

The rigid and nonrigid types of insulation are applicable in retrofit projects where it is possible to position the material for a smooth bond. A tight seal is necessary to achieve good insulating results. Coatings, wood paneling, or gypsum plaster board serve as protection against wear and tear for insulation added to the inside surface of walls. Insulation that is blown into cavities is perhaps the most popular insulating material because it will not alter the appearance of the building and can be applied with minimum inconvenience to the building's occupants. Holes are drilled into the wall surface, or access to the attic space is opened, and the insulation is blown into the cavity under pressure.

Some insulations, especially granular types which are blown in, have a tendency to settle and compact themselves over time, thereby reducing their insulating quality. Additionally, when installing insulation it is important that the vapor barrier be properly positioned since moisture will negate the insulating effect. Consideration should also be given to assure that the selected insulation is not a fire or smoke hazard, or that building codes do not restrict the use of the insulation for its proposed application.

To determine the insulating quality of the surface after insulating materials have been added, (U_P), the original insulating quality (U_E) of the surface and the R-value of the insulation must be determined. The R-value defines the insulation's ability to resist heat flow and is defined as the reciprocal of the insulation's U-value. The following equation can be used to find U-retrofit (U_P) by knowing the existing U-value (U_E) and the R-value of the new insulation.

$$U_P \text{ (retrofit)} = \frac{1}{\frac{1}{U_E} + R}$$

where: U_P (retrofit) = the proposed insulating quality of the improved surface (Btu/hr/ft.^{2}/°F).

U_E = the initial insulating quality of the unimproved surface (Btu/hr/ft.^{2}/°F)

R = new insulation rating (hr/ft^2/°F/Btu).

°F = the difference between the average outside and inside winter temperatures.

Insulating materials and their respective R-values per inch of thickness as well as their installed cost are shown in table 5-13, Building Insulating Materials. These are intended to serve as design estimates. Particular specifications should be obtained from manufacturers.

As the proposed thickness of the new insulation increases, so does its total R-value (R total = R per inch x inches thickness). Iterative calculations are required when making the optimum decision regarding insulation thickness and type.

Preliminary data collection (Applies to Options A-3.1 and A-3.2)

- Determine the construction type and thickness of the individual exterior components.
- Measure the width of any roof or exterior wall cavity.
- Measure the total square footage of each uninsulated exterior surface.
- Determine the orientation (north, south, east, or west) of any walls to be insulated. If shading occurs, then regardless of the actual orientation, treat it as a north wall, as this does not include a direct sunshine component.
- Determine the average winter inside and outside temperatures. (See table 5-1).
- Determine the heating degree days for your area. (See figure 5-13). Determine the mean solar radiation (insolation) in langleys, and latitude of your area, from figure 5-15.
- Measure or estimate the total heating system efficiency factor, (See appendix B, table B-3).
- Estimate solar-heat absorption coefficient of the walls:

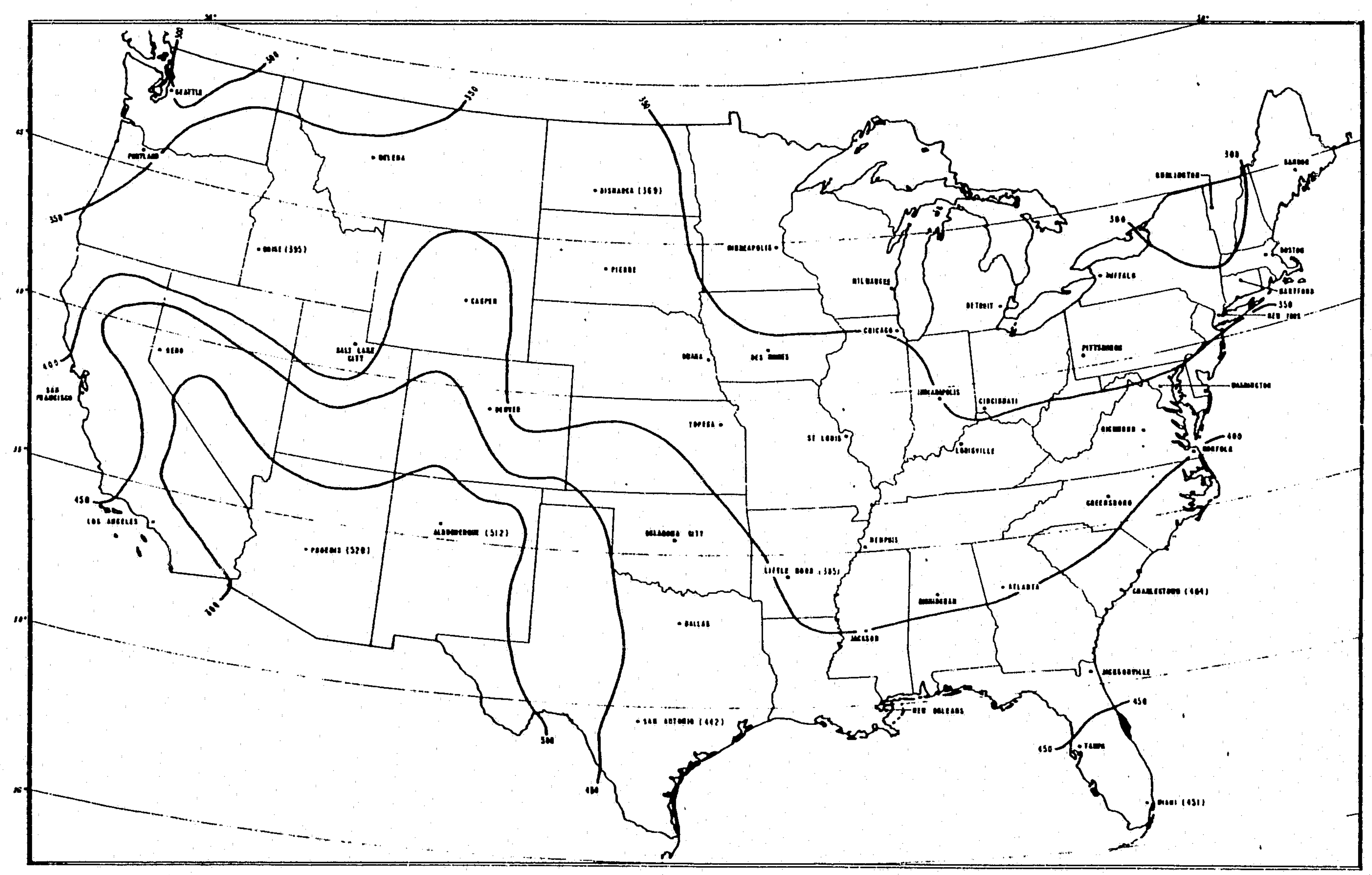
  light colors = 0.3
  dark colors = 0.8

Table 5-13. Building Insulating Materials

INSULATION				
Description	R-Values (hr x ft^2 °F) / Btu	Installed ($/Unit)(1)	Installed Cost in Standard ($/Unit/R)	Percent Savings Wall (3)
Poured in Place				
Fiberglas Wool	4/in.	$1.20/ft^3	$.029	71
Mineral Wood	3/in.	$1.15/ft^3	$.032	68
Vermiculite or Perlite	2.7/in.	$1.50/ft^3	$.046	65
Rigid				
Fiberglas 30/ft^3				
1" thick	4.3	$ .43/ft^2	$.01	46
2" thick	8.5	$ .66/ft^2	$.078	63
Fiberglas 60/ft^3				
1" thick	5.5	$ .59/ft^2	$.107	52
2" thick	11	$ .98/ft^2	$.089	69
Urethane, no paper backing				
1" thick	7.14	$ .47/ft^2	$.066	59
2" thick	14.3	$ .76/ft^2	$.053	74
Nonrigid				
Fiberglas Blankets or Batts				
3.5" thick	11	$ .25/ft^2	$.023	69
6" thick	19	$ .37/ft^2	N/A	N/A
8.5" thick	30	$.53/ft^2	N/A	N/A
Mineral Fiber Batts				
3" thick	11	$ .23/ft^2	$.021	69
6" thick	19	$ .33/ft^2	N/A	N/A
10" thick	30	$ .47/ft^2	N/A	N/A
Blown or Expanded				
Blown Cellulose Fiber	5/in.	$ .11/ft^2	$.022	78
Urethane Foam	7/in.	$1.05/ft^2	$.233	83
Urea Formaldehyde	4.8/in.	$1.15/ft^2	$.240	77

(1) For roof or wall insulation
(2) Wall of standard 2" x 4" construction, studs, 16 inches on center
(3) Assumed installed on (inside of or in an) interior cavity of standard wall; original wall U-value = 0.25

Figure 5-15. Annual Mean Daily Solar Radiation in Langleys



A-3.1 INSULATE ROOFS

If the building is three stories or less, the installation of roof insulation can provide significant energy savings.

a. Preliminary data collection (See Option A-3)

b. Energy savings (MBtu/year). To determine the yearly energy savings, use the following procedure:

- o Determine the U-value of the existing roof or estimate U_E as:

  $U_E = 0.25$ Btu/hr/ft.^{2}/°F

- o Using the U-value (existing) calculated for the roof, enter figure 5-16 as appropriate at your heating degree days. Following the direction of the example line, intersect at the appropriate points for langleys and U-value. Read out yearly heat loss per square foot of roof on the appropriate absorption coefficient line.

- o Repeat the complete procedure outlined in the introduction to A-3, Building Insulation.

- o Calculate the annual heat loss savings factor as follows:

  Heat Loss Savings Factor (10^3 Btu/ft^2/year) = Existing Roof Heat Loss (10^3 Btu/ft^2/year) - Retrofit Roof Heat Loss (10^3 Btu/ft^2 year)

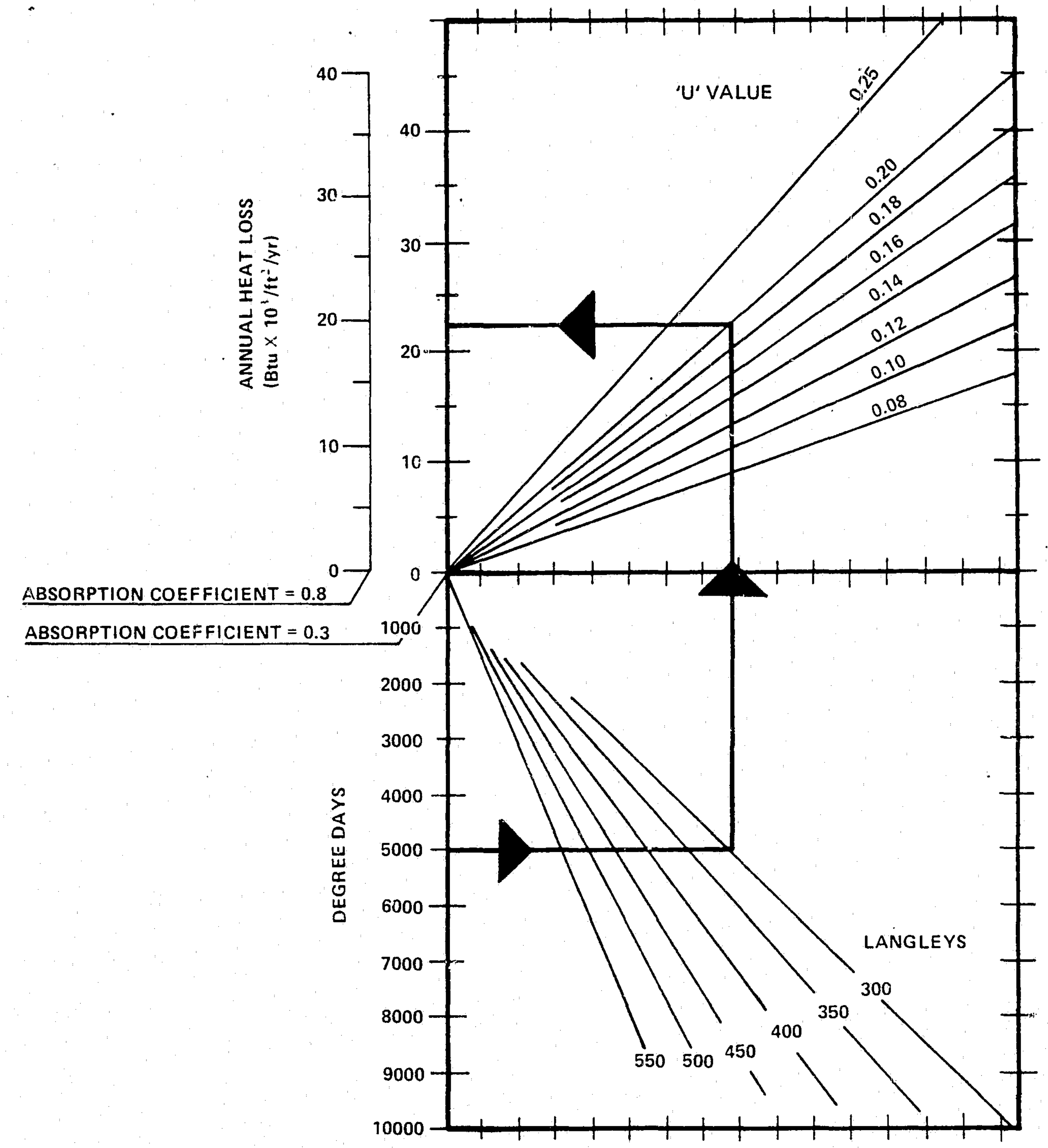
- o Energy Savings (MBtu/year) = Heat Loss Savings Factor

  $$\frac{(10^3\ \text{Btu/ft}^2\text{/year}) \times \text{Area of the roof to be insulated (ft}^2\text{)}}{\text{HEF} \times 10^3}$$

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($) - An insulation contractor can provide prices and the type of insulation that can be used. As an estimate, the costs per unit of insulation by area or volume in table 5-13 can be used to calculate the capital cost for installing insulation in a roof. Costs to add insulation to a roof where access is not readily available will be substantially higher.

Figure 5-16. Heating - Annual Heat Loss Through Roof



A-3.2 INSULATE WALLS

The insulating character of a wall is defined by the parameter U. The effect of adding insulation will be that of reducing the U-value, indicating decreased heat exchange. As an order of magnitude approximation, U for an uninsulated exterior surface may be taken as .25 Btu/hr/ft.^{2}/°F.

a. Preliminary data collection (See Option A-3).

b. Energy savings (MBtu/year). To determine the yearly energy savings through each wall, use the following procedure:

- Determine the U-value of the existing wall or estimate the U-value as:

$$U_E = 0.25 \text{ Btu/hr/ft}^2/°\text{F}.$$

- Using the U-value (existing) calculated for each wall, enter figure 5-17 or 5-18, as appropriate, at your heating degree days. Following the direction of the example line, intersect at the appropriate points for langleys, orientation and U-value. Read out yearly heat loss per square foot of wall on the appropriate absorption coefficient line.

- Repeat the complete procedure outlined in the introduction to A-3, Building Insulation, for each different orientation and U-value (U_E) of the wall to be insulated and for each retrofit U-value (U_P).

- For each wall, calculate the annual heat-loss savings factor as follows:

  Heat Loss Savings Factor (10^3Btu/ft^2/year) = Existing Wall Heat Loss (10^3Btu/ft^2/year) - Retrofit Wall Heat Loss (10^3Btu/ft^2/year)

- Energy Savings (MBtu/year) = Heat Loss Savings Factor (10^3Btu/ft^{2}year) x $\frac{\text{Area of wall to be insulated (ft}^2\text{)}}{\text{HEF x }10^3}$

c. Energy cost savings/year = Energy savings (MBtu/year) x \$/MBtu.

d. Capital cost (\$) - An insulation contractor can provide prices and the type of insulation that can be used. As an estimate, the cost per unit of insulation by area or volume given in table 5-13 can be used to calculate the capital cost for installing insulation in existing walls. Costs to add insulation to walls where access is not readily available will be substantially higher.

Figure 5-17. Heating - Annual Heat Loss Through Walls Latitude > 35° N

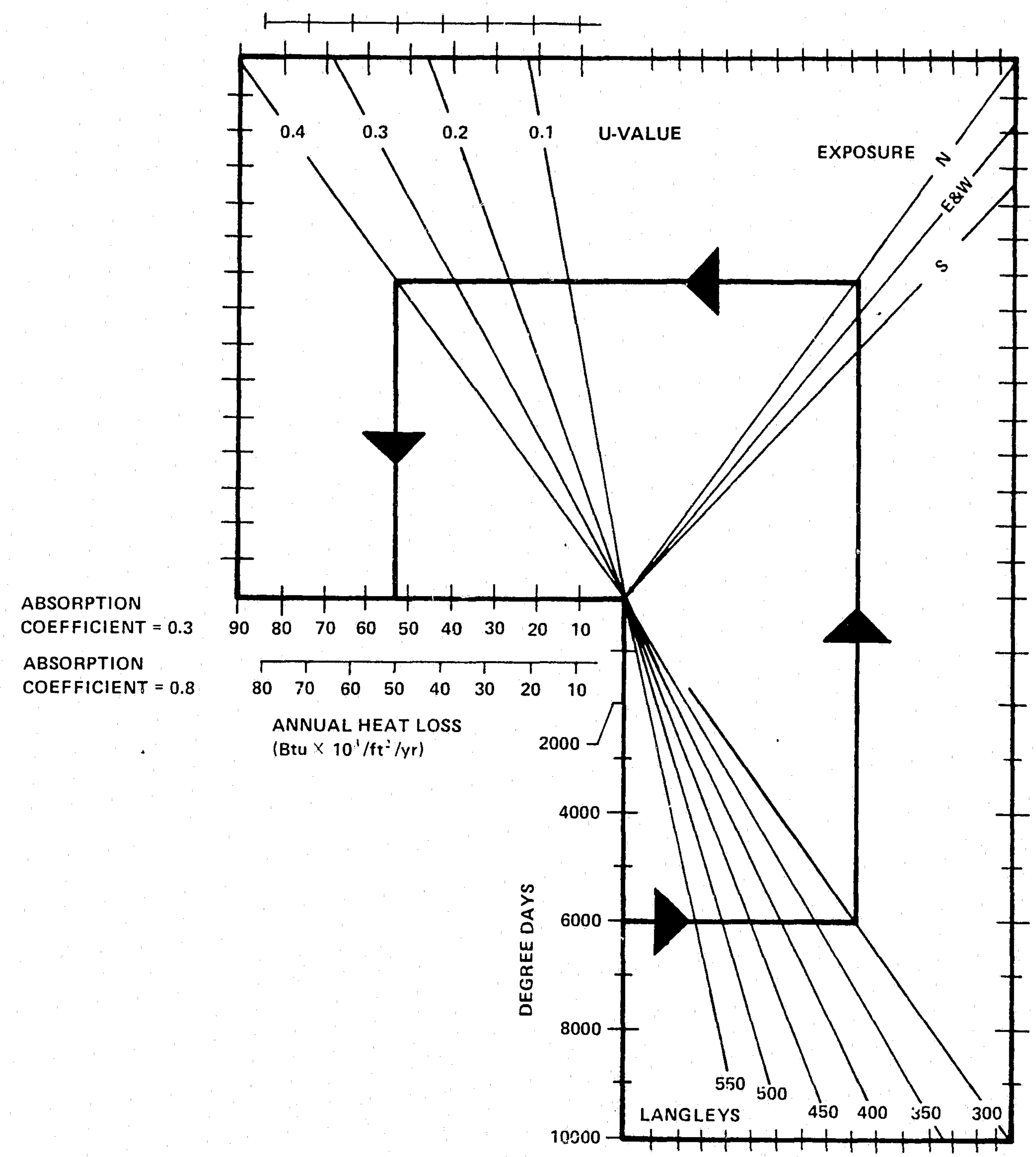
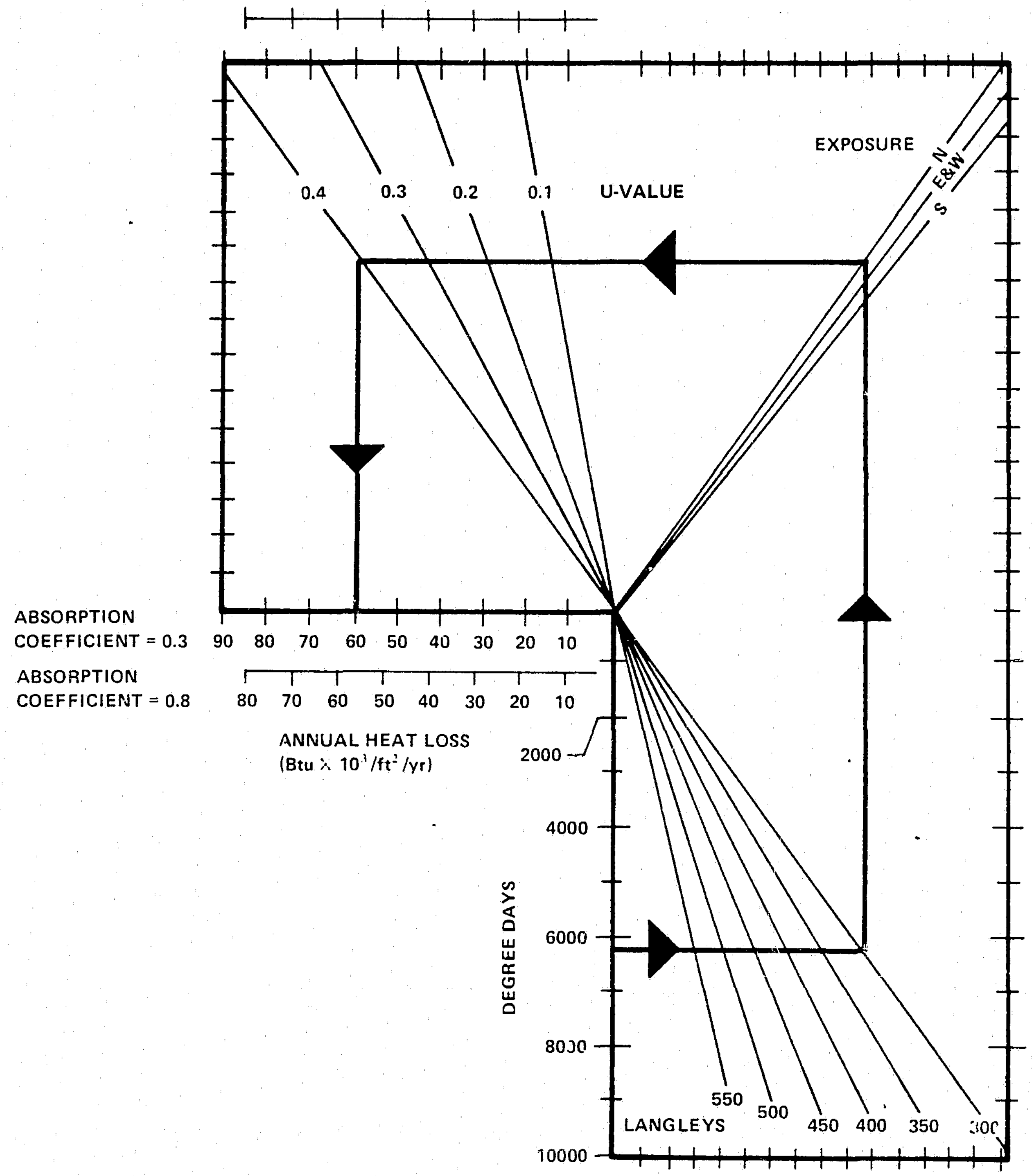


Figure 5-18. Heating - Annual Heat Loss Through Walls Latitude < 35° N



A-4. INSTALL DOUBLE-GLAZED/STORM WINDOWS

Converting to double-glazed windows can cut in half the heat lost through single-glazed windows. The actual savings also depends on solar radiation and wind.

Heat loss is greatest through windows of north exposure and least through windows of south exposure. If storm windows are added to the existing windows, consider using reflective or tinted glass to reduce solar gain and glare in summer. (Refer to Cooling Section).

Storm windows may be applied either to the outside or inside of existing windows. If the existing windows and frames are of poor construction, the storm windows should be fitted on the outside when possible.

The space between the storm window and the existing window should be vented to the outdoors and provided with drainage weepholes to prevent moisture buildup.

In all cases, whether storm windows are added or single windows are replaced by double, the frame of the selected unit should not form a heat bridge. Each frame should incorporate a thermal break between inside and outside surfaces. Such frames are commercially available. This is particularly important in frames made of metal, which readily conducts heat. A more desirable framing material is wood, which is a poor heat conductor.

a. <u>Preliminary data collection</u>

- o Measure the area of all single-glazed windows.
- o Record the orientation (N, S, E, W) of the window area.
- o Use figure 5-15 to identify the annual solar radiation (insolation) in langleys that your area receives, and your latitude.
- o Determine heating degree days HDD for your area (figure 5-13).
- o Measure or estimate the total heating system efficiency factor (HEF). (See appendix B, table B-3).

b. <u>Energy savings (MBtu/year)</u> - To calculate the energy savings use figure 5-19 or 5-20. Follow the direction of the example line. Intersect with the appropriate number of langleys and the window orientation. Repeat the procedure for the other window orientations and then for the double glazing of each window orientation. For each window orientation:

$$\text{Energy Savings (MBtu/year)} = \frac{[\text{Single Glazing Heat Loss } (10^3\text{Btu/ft}^2\text{/year})] \times \text{Window Area (ft}^2)}{\text{HEF} \times 10^3}.$$

c. <u>Energy cost savings/year</u> = Energy savings (MBtu/year) x $/MBtu.

Figure 5-19. Yearly Heat Loss Through Windows Latitude 35° N - 45° N

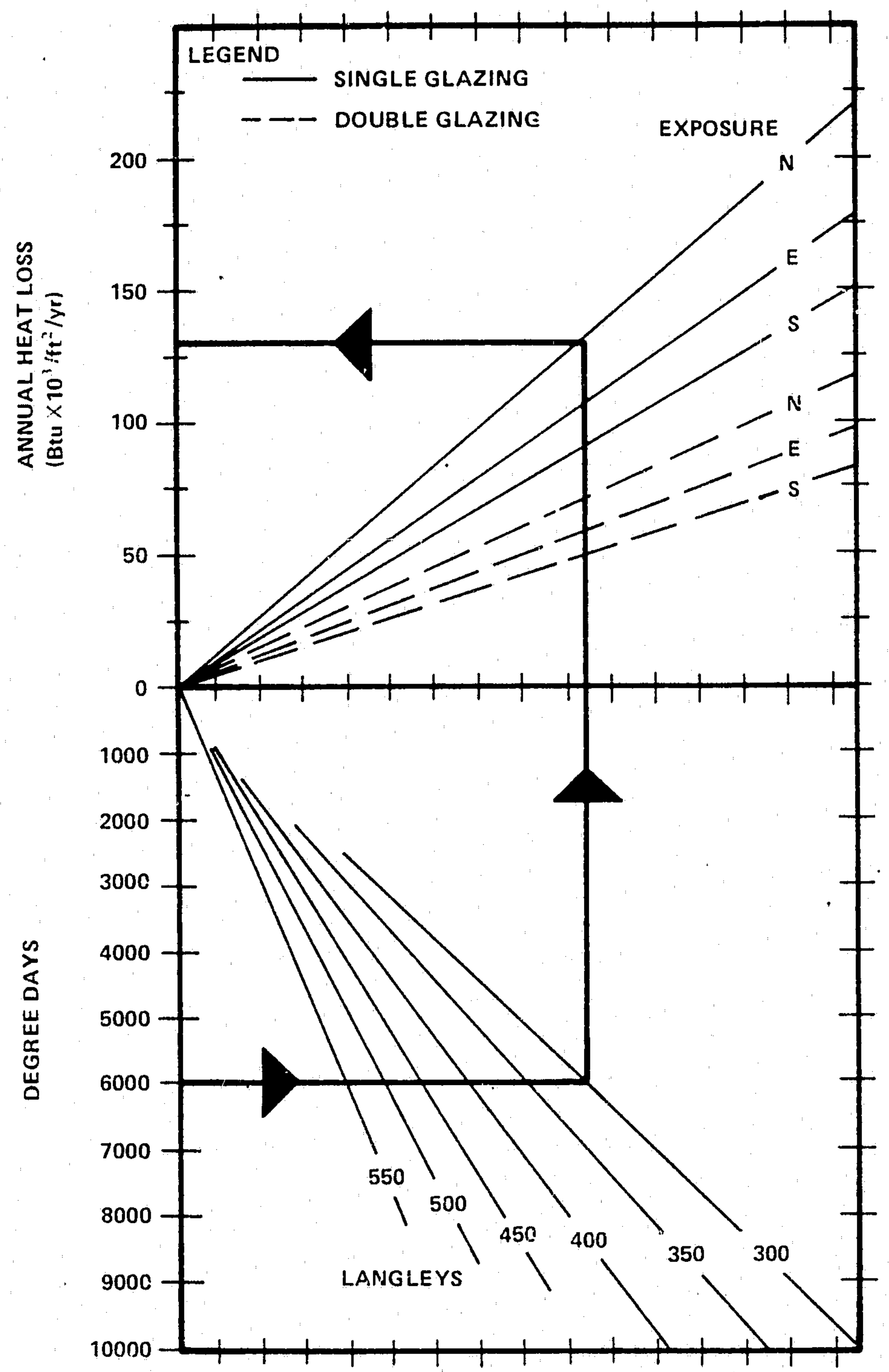
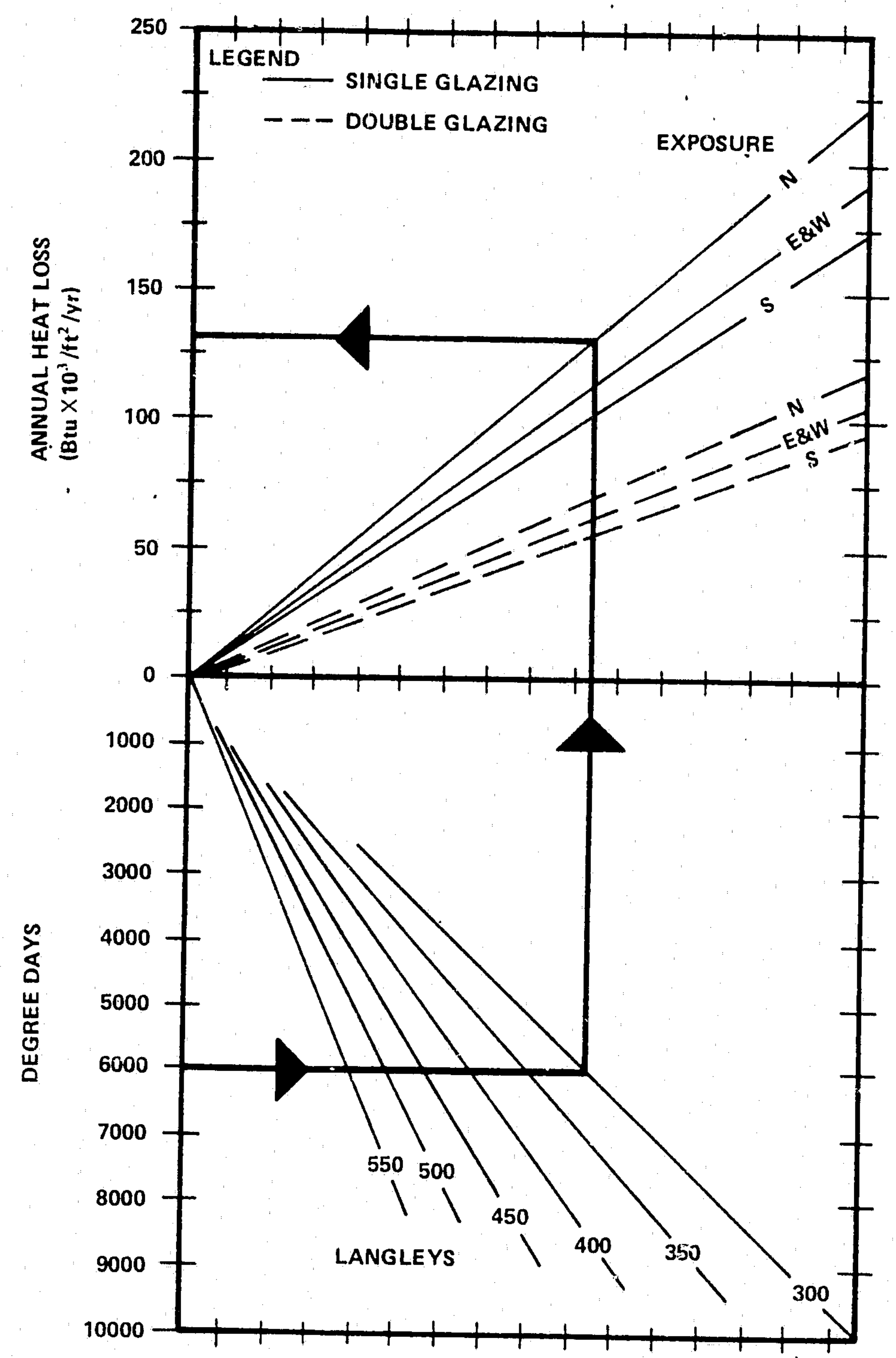


Figure 5-20. Yearly Heat Loss Through Windows Latitude 25° N - 35° N



d. Capital cost ($) = A window installation contractor can provide a firm price. For estimating purposes, the cost should not exceed $15 per square foot of window area. If inmates are used to build wood/polyurethane storm windows, the cost may be reduced to less than $8 per square foot. Although these storm windows may not be especially attractive, if properly sized and weatherstripped, they can be as effective as commercially installed storm windows.

A-5. INSTALL THERMAL BARRIERS TO FURTHER REDUCE HEAT LOSSES THROUGH WINDOWS DURING UNOCCUPIED HOURS

Most administrative areas are unoccupied for more hours per week than they are occupied. A major portion of the unoccupied hours occur at night when the rate of heat transfer is highest. During night unoccupied hours, windows can be covered with thermal barriers or shutters to decrease heat transmission losses. Thermally insulated barriers may be applied to the inside of the building and can be arranged to slide in a track or fold back into the window reveal or onto the face of the wall. When closed, the barriers will provide an additional seal over the window, but need not be airtight. The major portion of the total cost is in labor for construction and fitting rather than the cost of materials. Thermal barriers should, therefore, be selected or designed to have the best insulating value attainable for a given thickness.

If a permanent thermal barrier is installed to cover an existing window, use a U-value of 1.1 for a single-glazed window and estimate the U-value of the proposed barrier. To calculate the heating energy savings, use the wall insulation retrofit option (Option A-3.2). Figure 5-21 assumes the daily opening and closing of the barrier and therefore is inappropriate when permanently covering up a window opening.

An alternative to shutters are insulating shades or draperies which are available in thermal resistances up to R-9. These are less cumbersome and cheaper to use than rigid barriers, but tend to be less effective.

a. Preliminary data collection

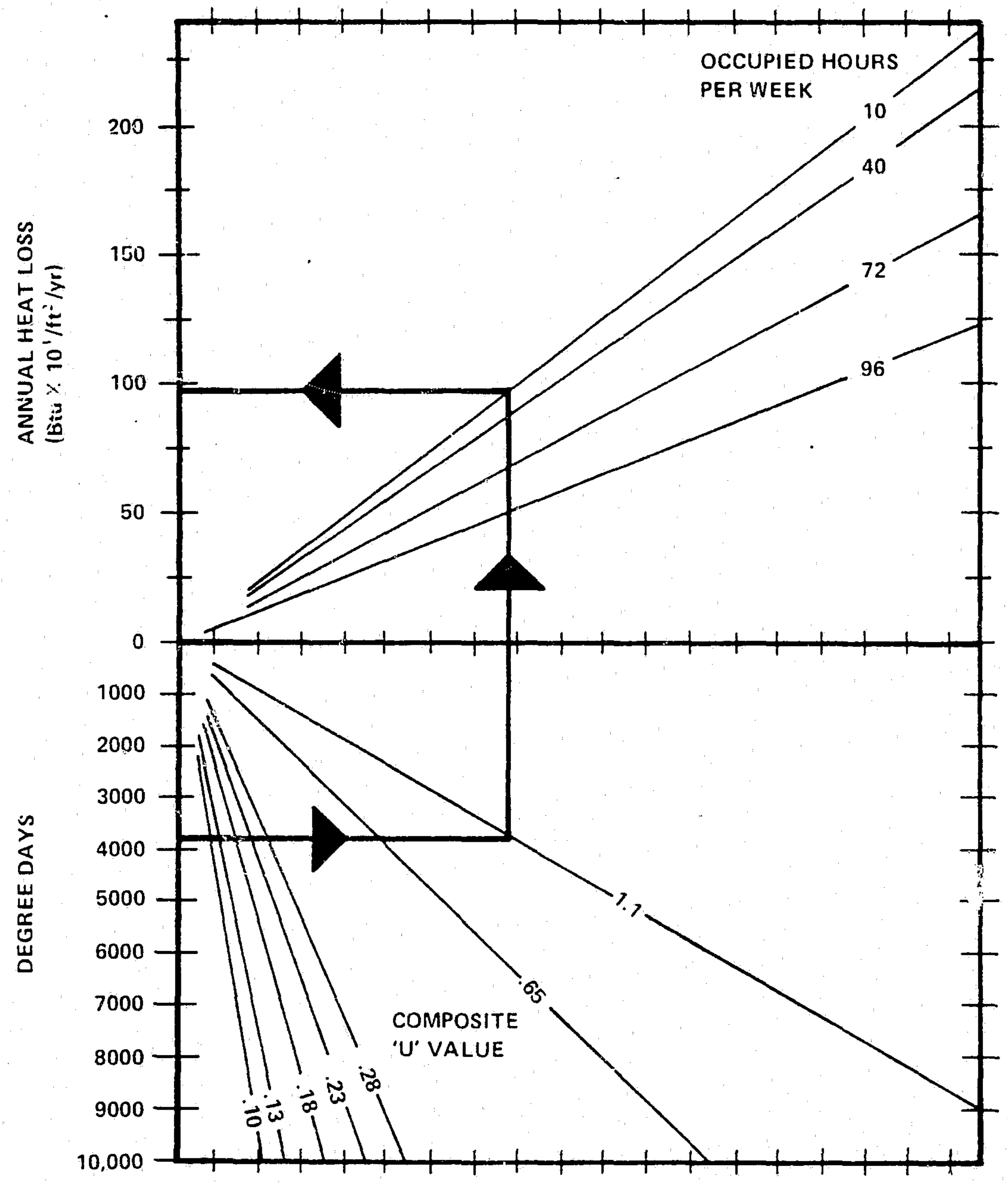
- o Measure the area of all windows for which drapes or shutters are desired.
- o Determine the heating (HDD) days for year area (figure 5-13).
- o Estimate the existing U-value of your windows; use 1.1 for single glazing, 0.55 for double, and 0.35 for triple.
- o Determine the composite U-value:

$$\frac{1}{\frac{1}{U \text{ (window)}} + \frac{1}{U \text{ (barrier)}}} = U \text{ (composite)}$$

If the U-value of the thermal barrier is not known, assume a value of 0.25 Btu/hr/ft^2/°F.

- o Measure or estimate the total heating system efficiency factor (HEF). (See appendix B, table B-3).

Figure 5-21. Heating - Annual Heat Loss for Windows with Thermal Barriers



b. Energy savings (MBtu/year). Enter figure 5-21 at the appropriate degree days, follow the direction of the example line, intersect at appropriate points for composite U-value and occupied hours per week. Read out yearly heat loss per square foot of window. Repeat the complete procedure for the retrofit composite U-value.

$$\text{Energy savings (MBtu/year)} = \frac{[\text{Existing Annual Heat Loss } (10^3\text{ Btu/ft.}^2\text{/year}) - \text{Retrofit Annual Heat Loss } (10^3\text{ Btu/ft.}^2\text{/year})] \times \text{Window Area (ft.}^2)}{\text{HEF} \times 10^3}$$

c. Energy cost savings/year = Energy savings (MBtu/year) x $/MBtu.

d. Capital cost ($). The cost of purchasing and installing thermal barriers will vary according to size and type of window, materials used in construction and ease of fitting. Quotations should be obtained from local contractors to determine the cost but for an estimate, assume $6.00/square foot of window for a folding barrier, and $5.00 per square foot for insulating shades.

A-6. INSTALL LOADING DOCK DOOR SEALS

Installing loading dock door seals to prevent cold air from entering the building through loading docks can provide an energy savings. A dock door seal will prevent cold air from entering a building while a truck is being loaded or unloaded by sealing the area between the door frame and the truck. Dock seals are used when loading docks open directly to the outdoors.

a. Preliminary data collection

- o Count the number of loading dock doors that do not have door seals and are in use in the winter.
- o Estimate the number of hours per winter that they are used.
- o Measure or estimate the total heating system efficiency factor (HEF). (See appendix B, table B-3).
- o Estimate the Btu/hr/door for your climate from following table:

Zone 1	50,000 Btu/hour/door
Zone 2	40,000 Btu/hour/door
Zone 3 & 4	30,000 Btu/hour/door

b. Energy savings (MBtu/year) =

$$\frac{\text{Btu/hour/door} \times \text{number of doors} \times \text{number of hours of winter use}}{\text{HEF} \times 10^6}.$$

c. Energy cost savings/year = Energy savings (MBtu/year) x \$/MBtu.

d. Capital costs (\$). Dock seals can be installed in the range of \$1,500 to \$2,500. Check with manufacturers of loading dock doors for firm prices.

A-7. INSTALL VESTIBULES TO REDUCE INFILTRATION

Infiltration can be reduced by installing vestibules or doors that open to the outside to provide an air lock.

High-traffic entrances, entrances exposed to severe weather conditions, or excessively drafty doorframes can be greatly improved with the addition of vestibules. To simplify construction, vestibules can be built by unskilled labor using any material for the walls, and a prehung entrance door.

a. Preliminary data collection

- o Measure the size of the existing door, and determine the condition of the existing seal.
- o If much door-related infiltration exists, calculate the savings due to weather stripping the door, following the procedure in Retrofit Option A-2.
- o Determine that sufficient space exists to create a vestibule. At least twice the length of the interior door's opening width is normally required.
- o Estimate the number of times the door is opened per hour, and the hours per day that the door is in use.
- o Determine the heating or cooling degree days (HDD or CDD)* for your area. (See figures 5-13 and 5-14).
- o Determine the average indoor temperature.
- o Measure or estimate the total heating system efficiency factor (HEF or CEF)*. (See appendix B, table B-3).

b. Energy savings (MBtu/year). To determine the energy that can be saved from installing a vestibule, it is necessary to determine the energy used per year because of infiltration. Use the following steps:

- o To determine the infiltration in cubic feet per minute (cfm) that can be reduced by a vestibule, enter figure 5-22 at the appropriate passages per hour and intersect with the "without vestibule" line and the "with vestibule" line and determine the difference between the two from the left axis. This will give infiltration reduced by a vestibule in cfm.
- o To determine the yearly energy saved by this reduced infiltration, enter figure 5-23 at the appropriate degree day line, intersect with the indoor temperature line, intersect with the hours of occurrence (occupancy) line and read out the million Btu (MBtu) per year saved (per 1,000 cfm of reduced infiltration) from the lefthand axis.

*If cooling is employed, repeat the calculations for cooling energy savings. Sum the heating and cooling energy savings to obtain the total energy savings.

Figure 5-22. Infiltration With and Without Vestibules

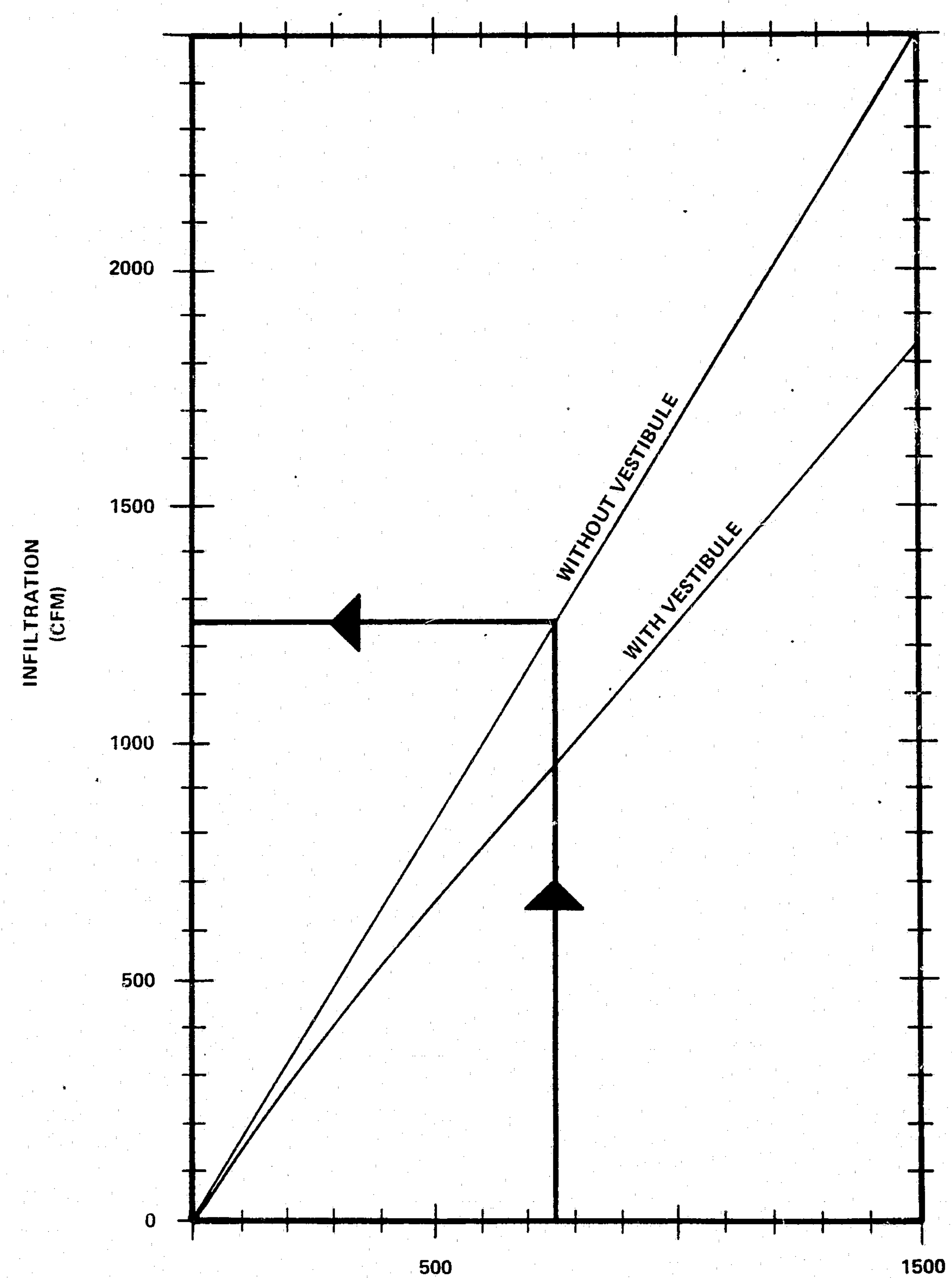
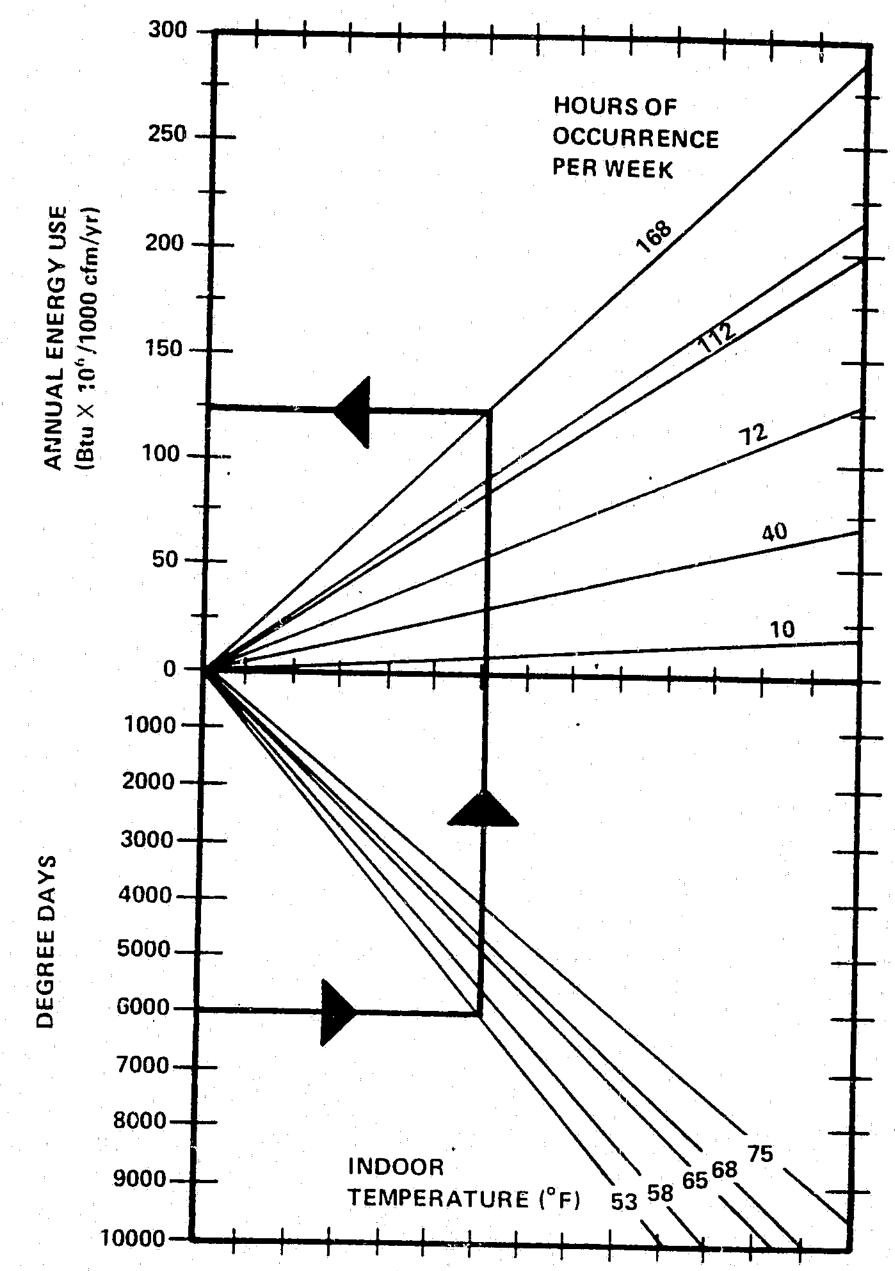


Figure 5-23. Energy Used Per 1000 CFM/Year, Outside Air



o Energy savings (MBtu/year) =

$$\frac{\text{infiltration reduced by vestibule (in cfm)}}{1000 \times \text{HEF}} \times \text{MBtu saved}$$

from reduced infiltration.

c. Energy cost savings/year = Energy savings (MBtu) x $/MBtu.

d. Capital cost ($). A quote for the installation of a vestibule should be obtained from a contractor. As a rough rule-of-thumb, vestibules with a single aluminum and glass door including automatic operators cost approximately $4,000 and vestibules with double doors cost approximately $4,500. But, where the existing opening lends itself to the installation of a vestibule, the estimated cost for a manually operated door may be reduced to $750. These installations do not include unusual configurations.

MISCELLANEOUS OPTIONS

M-1. CONTROL ELEVATOR OPERATION

M-2. CORRECT POOR POWER FACTOR

7. MISCELLANEOUS OPTIONS (M)

The options in this section include retrofit opportunities for elevators and correcting poor power factor at prisons. Although the percentage of energy used to operate elevators is small, it is an area where opportunities for energy savings exist. The energy cost savings frequently achieve simple payback periods of less than 2 years.

Capacitors are used primarily to eliminate electric utility power factor surcharges. In addition, they decrease electrical distribution system losses and increase system capacity. Whereas, it is cost-effective to install capacitors to eliminate surcharges, it is rarely cost-effective to install capacitors to reduce system losses and increase system capacity.

M-1. CONTROL ELEVATOR OPERATION

If multiple elevators are used in a building, energy can be saved by shutting down all but one during light traffic periods. This can be accomplished by installing time-clock controls on the elevators. Although most elevator generators will shut down automatically if not used (usually 1 to 5 minutes), this option prevents the generator(s) from restarting during low traffic periods. The elevator manufacturer can provide information about adding this feature to existing elevator controls.

a. <u>Preliminary data collection</u>

- o Observe the operation of the elevators during occupied hours. See if there are times when the elevators are used less frequently than others.
- o Estimate the number of hours that can be considered light traffic hours.
- o Observe whether or not the elevators are operational during unoccupied hours.
- o Sum the total number of hours each elevator can be shut down annually.
- o Obtain the horsepower rating of the elevator motor.

b. <u>Energy savings (kWh/year)</u> = 0.3 x 0.76 kW/hp x motor hp x number of hours elevators can be shut down per year.

c. <u>Energy cost savings/year</u> = Energy savings (kWh/year) x $/kWh.

d. <u>Capital cost ($)</u>. The purchase and installation of each time-clock operating device should not exceed $375.

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M-2. CORRECT LOW POWER FACTOR

The low power factor (PF) of an electrical system within a large building or a complex of buildings will increase the losses in the electric utility system and reduce the system's capacity. Many electric utility companies have a penalty charge for low power factor. Correcting power factor can provide for more efficient use of energy as well as a reduction in the cost of electricity. Electrical devices known as capacitors can be installed to correct low power factor.

a. Preliminary data collection. Check the electric utility bill to see if there is a penalty charge for low power factor. If the penalty charge cannot be found on the bill, contact the local utility and see if a charge has been included for low power factor. If so, then proceed with this option.

b. Energy savings. There is no actual reduction in the energy used by the equipment in the building. Power factor correction does reduce losses in the overall electric utility system and increase the system's capacity.

c. Energy cost savings/year = Annual power correction surcharge added to the monthly electric bill.

d. Capital cost ($). Capacitor power-handling capability is measured in Kilovolt-Amperes (KVA).* The higher the total KVA purchased, the lower the cost per KVA. An electric contractor or consultant can provide estimates for the amount of KVA of capacitors needed.

*See appendix B for definition

CHAPTER VI. SUPPLEMENTAL SUGGESTED ENERGY CONSERVATION OPTIONS

A. Introduction

To this point we have reviewed options which are considered to be more economically feasible for buildings such as those found in correctional facilities. Other possible energy conservation opportunities exist which may also be viable for your particular situation. These will be presented to you in two sections: those which are not normally justifiable except under special conditions (section B), and those whose effects are very difficult to measure directly (section C).

The suggested Energy Conservation Options (ECO) provide you with information so you can determine whether the option has some relevance to your particular facility. It does not provide enough information for use in performing actual savings calculations. A phone call to a local distributor or manufacturer's representative may help in making estimates for options that include commercially packaged items. If not, and you feel an option may have some applicability, contact your state energy office or one of the references listed in this handbook for more information.

B. Options With Simple Payback Periods (SPP) Normally Longer Than 5 Years.

The following options are building modifications which under normal circumstances would not be economically justifiable. However, should the facility require redesign, implementation of these options as part of the redesign package will help to reduce overall energy use within the facility.

1. Use buffer zones to reduce heat transfer. An internal buffer zone is an area that thermally separates interior conditioned spaces from the exterior, by maintaining a temperature within the buffer zone that is intermediate to the interior/exterior differential. A common example of this is the entrance double-door vestibule, where heat leakage from the interior maintains a temperature above the outside temperature at no cost, while the vestibule in effect increases the effective insulation of that part of the wall.

More ambitious efforts using this approach can be cost-effective, particularly if interior redesign or remodeling is being contemplated. Service and utility areas, such as storerooms or mechanical equipment rooms, can be grouped on the north wall of a building exposed to cold winters and maintained at a temperature 10°-30° F below the rest of the building, reducing heat loss by decreasing the effective wall temperature differential. For areas where cooling is the prime concern, these buffer spaces should be located on the south wall. Corridors, rest rooms, file areas, etc., can be located around the exterior of a building and function as buffers.

2. Insulate ducts in unconditioned areas. Substantial energy savings will result from insulating ductwork that conveys heating or cooling air through unconditioned spaces at temperatures very different from the duct air.

The addition of insulation will reduce the transfer of heat into and from the surrounding air and thereby reduce the load on the heating or cooling equipment. Insulation can also reduce much of the noise of the air flowing through the ducts.

As the temperature difference between the air in the duct and the air surrounding the duct increases, so does the heat transfer and economic effectiveness of an insulation retrofit. Ducts which are exposed to very hot or very cold air, such as those which run exterior to a building or in an attic or crawl space, will benefit most from the addition of insulation. The need to prevent condensation on low-temperature surfaces is also a consideration, and most of these insulations will require a moisture barrier to protect them from deterioration caused by moisture.

Typical insulation materials include semirigid boards and flexible blankets of fibrous, cellular, or bonded particle forms. These are attached to the ducts by adhesives, clips, or bonding. These materials, properly installed, will last the lifetime of the building.

Care should be taken that the selected insulation complies with applicable fire and smoke hazard standards and with local health and safety codes.

3. Convert hot water to recirculating system. The hot water system plumbing should be reviewed to determine if recirculation can be added or improved. The amount of uncirculated hot water should be determined. Pipe lengths in excess of 25 feet that carry hot water will result in waste - people run water to bring the water supply at the faucet to a usable temperature.

Most hot water systems do not have the capability of mixing unheated water with the supply water to reduce the supply temperature during mild weather when lower temperatures could be maintained. When adding a recirculating system, a three-way mixing valve can be added, together with a discharge temperature controller. With this modification, water returning to the tank can be blended with the heated water to reduce the supply temperature as required.

Further savings can be achieved by adding a time clock control to shut down the recirculating pumps when the building hot water is not in use.

4. Add attic ventilation to improve cooling. Some attics are poorly ventilated, allowing large quantities of heat to build up in the attic space. Temperatures of 180°F and over are not uncommon in hot climates with underventilated attics. This heat transfers through the ceiling into unoccupied areas, raising uncooled space temperatures 5°-20°F above similar space with well ventilated attics. Improved ventilation increases the effective insulating R value of the ceiling, thereby reducing the heat gain and consequently reducing the cooling load.

Energy savings will only accrue if mechanical cooling is being used to moderate indoor temperatures. However, it may be desirable to analyze this option in tandem with a mechanical cooling system being contemplated for installation.

An attic ventilator can be obtained in unpowered, wind-turbine versions or in powered, thermostatically controlled motor-driven versions. In continually windy areas, the turbine will prove to be about 30 percent less expensive to operate. In the following analysis the powered ventilator, more suitable to most areas, will be discussed. If turbine ventilators are chosen, reduce costs accordingly.

5. Prevent air stratification. In open areas with high ceilings (15 feet or more), the stratification of air in colder months can waste energy and cause discomfort to the people working or living in the building. To lessen the temperature differential between the ceiling and the floor, it is necessary to mix the air. This can be accomplished by installing a duct system to draw air from about 1 foot from the ceiling and transport it to the floor level or by using a ceiling fan to gently move the hot air near the ceiling down to floor level. These fans are inexpensive to install and operate. Twenty-five percent of the energy used to heat space with high ceilings can be saved if air stratification is eliminated.

This option is very attractive in multiple-story cell blocks. Frequently, inmates in the highest and lowest tiers are subject to temperature extremes. Therefore, by reducing air stratification, fans not only reduce the energy required to heat these cell blocks but they reduce the number of complaints by the inmates.

In secured areas, the use of a duct and fan system is recommended. Ceiling fan blades ("Casablanca" fans) can become dangerous weapons if not properly protected. Increased installation costs required to protect these fans from damage decreases the cost-effectiveness of this simple alternative.

6. Lower ceiling heights. In high ceiling areas, lowering the ceiling height can save energy. If a ceiling height is above 10 feet, and a high ceiling is not required, lowering the distance from the floor to the ceiling will save significant amounts of energy used for space conditioning and illumination.

For example, lowering the ceiling height from 25 to 20 feet decreases the volume of air by 4 percent per vertical foot, or by 20 percent overall in this case. (Assuming that the area of the ceiling and floor remain constant). Since the amount of energy required to condition air is directly proportional to the volume of the air, a decrease in that volume will result in a decrease in the amount of energy needed for conditioning (heating or cooling).

Lighting intensity is an inverse function of the square of the distance from source to object. Therefore, reducing the ceiling height by one half will quadruple the average intensity. Electricity is commonly more expensive per million Btu than other energy sources; therefore, reducing the number and/or size of lights required to maintain the same lighting intensity can result in large cost savings.

A suspended ceiling is a fast and inexpensive method of lowering the ceiling height. It will hide cracked or peeling paint as well as piping and wiring that run across the existing ceiling.

Lowering ceiling heights generally applies to administrative and other unsecure areas. Reducing ceiling heights in resident areas requires special design considerations to insure facility security. These special considerations can increase the capital cost of this retrofit option to the point where it is rarely cost-effective.

7. Use separate make-up air for exhaust hoods. Kitchen equipment exhaust hoods and other process equipment hoods frequently remove large quantities of hot air, which must be replaced by outdoor air. This make-up air is often introduced through the building HVAC system which heats it in winter and cools and dehumidifies it in summer to the level required to maintain occupant comfort within the building.

It is not necessary in most buildings for the make-up air supplied to exhaust hoods to be treated to the same degree required for the comfort of occupants. In fact, in cold weather, the temperature of the make-up supply air often need only be 50°-55°F, assuming it is introduced close to, or around the perimeter of, the exhaust hood. This relatively low-temperature air will not cause discomfort to occupants in the immediate area of the hoods, as the equipment beneath the hoods radiates large quantities of heat which will offset any cooling effect.

To reduce the quantity of energy wasted in preconditioning supply air to exhaust hoods, it is often advisable to install a supply-air system which is completely or partially separate from the rest of the building's HVAC system. In most cases, this separate system will consist of the necessary ducts, fans, dampers, etc. to draw in outdoor air and pass it through a heating coil or a cooling coil enroute to the exhaust hood. This will temper the air and maintain tolerable conditions immediately adjacent to the hood while not imposing unnecessary demands on the building's primary HVAC system.

(NOTE: The effectiveness of an exhaust hood in capturing heated air and fumes, smoke, steam, etc., is a function of the face velocity at the edge of the hood. To maintain a satisfactory capture velocity, large open hoods require large volumes of supply air. But face or capture velocities can be maintained and even increased while decreasing the volume of exhaust air by installing baffles or false hoods within an existing hood.)

8. Install a return-air system. Many buildings have heating, ventilating, and air-conditioning systems that operate on 100 percent outside air during the occupied period. If these systems are used during the unoccupied period to maintain constant space temperatures, outside air must be introduced. With the addition of return-air ducts to these units, the units may be cycled on 100 percent return air during the unoccupied period. The use of return air during the unoccupied period results in savings due to not having to heat or cool unnecessary quantities of outside air.

Additionally, if building usage pattern changes, 100 percent outside-air units may have return-air ducts added to them. They then operate during the occupied cycle on a mixture of return and outside air. Savings again would accrue from not having to either heat or cool quantities of unneeded outside air.

The cost of installation would vary with building construction. The equipment needed to make the necessary changes would be:

- o Return-air ducts
- o Return-air damper
- o Return-air damper motor
- o Return-air fan if needed

A local HVAC contractor should be contacted for cost justification.

C. Options Difficult to Calculate

The following options offer additional opportunity to save energy in your facility. They are very difficult to quantify in terms of energy cost-avoidance. Thus they cannot be ranked with other options in terms of economic feasibility.

1. Design lighting for specific work task. The orientation of lighting systems to provide lighting for specific work tasks can save energy by eliminating lighting in areas where it is not needed. This is especially true in areas where high levels of lighting are needed for work requiring very fine definition of detail. The design for the lighting of a specific work task can be performed in-house or by lighting designers.

2. Use low-volume flushometer valves in toilets. Replacing existing valve diaphragms with reduced-flow units will decrease water consumption. The flushing valves now installed may be high water consumers, permitting a large quantity of water to flow per use. Recently, new diaphragms have been designed which let through about one-half the water previously used. These diaphragms cost the same as the old ones. Low-volume diaphragms should be specified in future purchasing orders and installed during regular valve maintenance procedures.

3. Retune boilers. The reduction of excess air by retuning the boilers is a major step in improving efficiency. The lower limit of excess air is reached whenever there is incomplete combustion or flame impingement on the tubes. The main causes of excess air are:

- o Air leaks
- o Improper draft control
- o Faulty burner operation

The latter two cases, improper draft control and faulty burner operation, are the major reasons for excess air.

Boiler efficiency is reduced by excess air in that some of the heat released by the combustion process must go towards heating the excess air to the same temperature as the combustion products. Burners always supply more air than the amount needed to furnish the oxygen required for complete combustion. Even though excess air yields smokeless combustion and eliminates carbon monoxide, it also cools the flame and lowers temperatures in the combustion chamber. The reduction in flame temperature substantially lowers the rate of heat transfer in the boiler and further contributes to reduction in boiler efficiency.

As excess air is introduced, more nitrogen and unused oxygen will eventually leave the stack. Since the products of combustion are usually hotter than the steam or water in the boiler, large amounts of heat energy escape through the stack again lowering the boiler's efficiency.

4. <u>Shut off pumps during unoccupied hours</u>. When the building is unoccupied, shut off all of the pumps possible. Install a time clock or use an energy monitoring and control system (EMCS) controller to accomplish the shutdown. If pumps are found to operate continuously, including drinking water circulators, house pumps, city water boosters, circulating pumps, and chilled water booster pumps, then the installation of a time clock or other controller to shut off these pumps after occupied hours will save energy.

5. <u>Control waterside scale</u>. A layer of waterside scale as thin as one-tenth of an inch can drastically lower the heat transfer rate and reduce steam output. Packaged boilers with large steam generating surface areas and extremely high heat transfer rates cannot tolerate waterside scale. When scale is present, tube temperatures will exceed design temperatures, resulting in tube metal creep and rupture.

A chemical treatment program consisting of corrosion control, pH adjustment, hardness precipitation, and sludge conditioning will keep internal boiler surfaces free from scale, thus allowing maximum heat transfer rates.

6. <u>Reduce blowdown losses</u>. The purpose of blowing down a boiler is to maintain a low concentration of dissolved and suspended solids in the boiler water and to remove sludge in the boiler to avoid priming and carryover. There are two principal types of blowdown; intermittent manual blowdown and continuous blowdown. Manual blowdown (or sludge blowdown) is necessary for the operation of the boiler regardless of whether continuous blowdown is being used. The frequency of manual blowdown will depend on the volume of solids in the boiler makeup water and the type of water treatment used. While continuous blowdown requires a steady supply of additional energy (because the makeup water must be heated), these losses can be minimized with automatic blowdown control and heat recovery systems. Continuous blowdown also wastes internal boiler water treatment chemicals. Chemical savings must be added to fuel savings to determine total savings possible with precise blowdown control.

Automatic blowdown controls monitor the conductivity and pH of the boiler water, allowing the boiler to blowdown only when required to maintain acceptable water quality. Further savings can be realized by piping the blowdown water through a heat exchanger or through a flash tank with a heat exchanger. The percent of heat recovery will change with boiler operating conditions. The heat recovery range is 78 percent for a 15 psig boiler to 98 percent for a 300 psig boiler.

7. <u>Preheat heavy fuel oil to increase boiler efficiency</u>. Waste heat from flue gases, blowdown, condensate, hot wells, etc., or from solar energy may be used to preheat combustion oil, either in the storage tanks (low-sulfur oil requires continuous heating to prevent wax deposits) or at the burner nozzle. Heavy oils must be preheated to at least the following temperatures to obtain complete atomization:

No. 4 oil - 135°F
No. 5 oil - 185°F
No. 6 oil - 210°F

Heating beyond these temperatures will increase efficiency, but care must be taken not to overheat, as vapor-locking could cause flame-outs. The increased efficiency obtained by preheating oil could be as high as 3 percent but depends on the particular constituents of the oil.

8. <u>Reduce energy consumed by reheat systems</u>. "Reheat" refers to a system of air-conditioning which avoids the over-cooling of a space, not by reducing the volume of chilled air, but by tempering it with warm air to achieve the desired levels of temperature and relative humidity. The heat so employed is called reheat. It is a popular system because of its relatively low initial cost and its high degree of controllability. A variant of reheat is often employed in double-duct and multizone HVAC systems.

While convenient to use, these systems are extremely exorbitant in their energy consumption. In fact, the reheat function alone can easily consume as much energy per year as the HVAC system to which it is applied. Since reheat systems are used primarily to offset excessive cooling, the majority of waste due to reheat often occurs during milder weather and--if the system is left operating--during the night. The degree to which this occurs will vary with each system and the methods by which it is operated and controlled.

The four major HVAC systems which typically employ reheat are briefly discussed below, along with procedures for reducing the energy they consume.

a. <u>Terminal reheat systems</u>. Terminal reheat allows each zone to be individually controlled but wastes energy in the cooling system, as all of the supply air must be cooled to a low enough temperature to meet the most critical load zone and then reheated for zones of lesser loads to avoid overcooling.

As with single-duct systems, energy can be conserved by reducing the supply air volume. Many reheat systems are controlled at a fixed supply temperature of around 55° wet bulb temperature. To conserve energy, fit controls to reschedule the supply air temperature upward according to demands of the zone with the greatest cooling load. If one zone has cooling loads grossly in excess of all others the controlling thermostat should be located in that space.

The greatest quantity of energy can be saved by adding variable air volume (VAV) boxes to each of the major branch ducts. Each VAV box should be controlled by a space thermostat located in its particular zone, and its associated reheat coil should be provided with controls to prevent reheat until the VAV box has reduced the zone supply air volume to 50 percent.

In buildings where a reheat system supplies zones of different occupancy, add dampers and control valve to enable water to be shut off during unoccupied times.

b. Multizone systems. Most existing multizone units now have separate heating and cooling coils for each zone supply duct, so the supply air is heated or cooled only to meet the zone load demand. These new units use far less energy that old units with common coils. If renovations are comtemplated for an existing multizone unit or if the existing multizone unit is at or near the end of its useful life, replacement, using a multizone unit with individual zone coils, should be considered.

c. Dual-duct low-velocity systems. Dual-duct low-velocity systems supply hot and cold air in individual ducts to the various zones of the building. The mixture of hot and cold air maintains the desired zone conditions. Control of mixing is normally achieved by automatic dampers in the branch ducts, each damper being positioned according to the dictates of the space thermostat. Each duct should be analyzed as a single-zone system to determine whether the air volume or its temperature set-point can be advantageously changed to conserve energy. Reduce the temperature of the hot duct and increase the temperature of the cold duct to that point where the heating and cooling loads of the most critical zone can be met.

Return air is a mixture of all zones and reflects the average building temperature. In some designs of central station equipment, it is possible to stratify the return air and the outdoor air by installing splitters. In this manner, the warmer of the two air flows (either return or outdoor) can be siphoned to favor the warm deck while the cooler air can be directed toward the cold deck. This method reduces both heating and cooling loads.

d. Dual-duct high-velocity systems. Dual-duct high-velocity systems operate in the same manner as low-velocity systems, except that the supply fan runs at a high pressure and each zone requires a mixing box with sound attenuation.

Considerable quantities of energy are required to operate the fan at high pressure, and a close analysis of pressure drops within the systems should be made, along with a reduction in fan pressure to the minimum required to operate the mixing boxes. To reduce system pressure, replace existing high-pressure mixing boxes with lower-pressure types.

9. Control steam shutoff at selected distribution mains. Many buildings contain equipment that utilizes steam on a year-round basis. The same buildings may contain mechanical equipment such as heating and ventilating units that utilize steam only during part of the year.

Year-round steam usage would be typically found in buildings with kitchens, laundries, process equipment, and in hospitals.

In buildings with combined functions, steam distribution to equipment that utilizes steam only part of the year may be isolated and steam shut off at selected distribution mains.

Savings will be incurred because less steam production is required and, in instances where steam lines are not properly insulated, overheating conditions will be eliminated.

10. Reduce steam distribution pressure. In many instances steam boilers are run during occupied periods of the day at pressures ranging up to 125 psi. This steam pressure may be needed to satisfy the requirements of mechanical equipment associated with laundries or process applications.

Building mechanical systems such as heating, ventilation, and air-conditioning equipment supplied by steam from the same boiler system may function on much lower steam pressures, especially during periods when the building is unoccupied.

With common steam lines from the boiler to high- and low-pressure steam-using equipment, time clocks with pressure-reducing valves may be added to the system to cause the steam boilers to operate on lower steam pressure during the unoccupied period. Savings in steam production will result.

11. Control steam shutoff to buildings. In many instances a majority of the buildings served by a central utility plant are unoccupied during such as nights, weekends, and holidays.

Without a means of preventing and regulating flow of steam to unoccupied buildings, unnecessary costs are incurred for steam production.

A building optimizer can be provided which should function as follows:

- The optimizer should contain a 7-day time clock with provision for weekend skip. It should be supplied with 120-volt alternating current to power its clock mechanism and should have a 72-hour spring reserve feature in the event of power failure.

- The optimizer should have built-in measured variables of the building U-factor and inside and outside temperature conditions. Building mass is factored in by predetermined dial settings of 1 to 4; one for heavy building mass, 4 for light building mass, with intermediate settings if required.

- The optimizer must have a preset value for occupied space temperature set-point and a preset value for unoccupied space temperature set-point.

- The instrument should have a normal preheat setting to bring the inside space temperature of the building up to satisfactory space conditions for normal winter weather and an advanced preheat setting to bring the building up to satisfactory space temperature conditions following a weekend shutdown.

o The optimizer controls an automatic steam valve located downstream of the building pressure-reducing valve.

o During occupied hours the building will be controlled at normal space temperature conditions (65°F).

o During unoccupied hours the building will be controlled at the lower unoccupied space temperature (55°F).

12. Repair air leaks in pneumatic systems. Compressed air as a power distribution system has many advantages; but as an overall energy system, its efficiency can be improved. The need to minimize energy consumption requires consideration of improvements that can be incorporated into compressed-air systems. One simple way to conserve energy in the plant compressed-air system is to reduce air leaks in the distribution system and air-powered devices.

Some plant air system leaks exceed 50 percent of the capacity of the compressors. Unlike leaks in hydraulic and steam systems, air leaks cause no readily obvious problems or discomfort to maintenance personnel. Leaks are often undetected, and can become a permanent, parasitic power drain on the system. A first step toward reducing this waste is identification of the problem. All plant air compressors should be equipped with capacity gages that measure flow during dynamic operating conditions. Capacity gages should not be confused with test devices such as orifices that require interruption of operation. Total system leaks are easily measured by operating compressors during downtime.

CHAPTER VII. RECOMMENDED OPERATION AND MAINTENANCE PROCEDURES AND ENERGY CONSERVATION PRACTICES

A. Introduction

The most modern, efficient, well-designed piece of hardware can quickly become a rusting hulk of an energy hog if proper maintenance is not performed. Conversely, like an antique car, even an obsolete unit can be spruced up, and often made to function as well as a new unit, if maintenance is properly done. In the same way, the manner in which the functioning of the building and the operation of its systems impacts on energy use can be optimized without changes in comfort, procedures, or safety. If maintenance is the building's equivalent of a car's "tuneup," then its operation is analogous to the driver's foot on the pedal. Maintenance defines how well the system can perform, and operation indicates how well it will perform.

Good maintenance is critically important to a program of energy management. Not only will effective maintenance help ensure efficient operation of equipment and system, but it also will help prolong the usable life of equipment. Good operational procedures allow building energy use to be further trimmed, and can improve the quality of occupancy while decreasing waste. The newly efficient energy-using system has not really changed. The operation of the system, which was intended for many different uses or users, has now been tailored to the use and user which it must serve, and only that one.

All guidelines presented here should be followed to restore the efficiency which equipment is capable of achieving, and to maintain that efficiency year-round. Inspection of many of the items mentioned also will provide you with some idea about the effectiveness of the current maintenance program, and the condition of equipment, some of which may need adjustment, repair, or replacement.

Realize that these guidelines are general only. Wherever possible, appropriate equipment manufacturers should be contacted to obtain pertinent literature describing the suggested maintenance procedures. Otherwise, those who regularly install such equipment, or who design heating and cooling systems, should be consulted.

Similarly, operational changes have avenues to conserve energy that should be emphasized. Operational changes can complement other types of energy conservation measures. Be careful, however, not to use operational savings as an excuse not to undertake other potentially more beneficial measures.

Operational savings will, in some cases, cause minor deviation from accepted standards of comfort. Some deviations may be more noticeable than others. Remember that each building represents a unique situation. As such, the guidelines outlined herein should be recognized as general and should be tailored to the building involved.

Energy conservation practices fall into the mid-ground between operation and occupancy. These practices and suggestions show how the occupants of a facility can, through simple actions and energy awareness, have a great impact on the level of energy used by the "nonautomatic" system (those mechanisms, such as light switches, over which the individual has control). Time spent in judicious selection of those ideas suited to your facility, and consideration of its mission and its occupants, will pay back greatly in energy saved.

B. Operation and Maintenance Procedures

Maintenance of building structures and equipment is a very effective method of reducing energy use. Heating, ventilating, and cooling systems usually account for the largest portion of energy use in typical nonindustrial buildings, followed by hot water systems. It is especially important that these major energy systems be operated and maintained in a manner that will maximize their efficiency. Operation and maintenance tasks identified in the following lists should be done on a scheduled basis.

1. Heating systems

a. Boilers (General)

(1) Observe the fire when the unit shuts down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace as necessary.

(2) Inspect the nozzles or cups of oil-fired units on a regular basis. Clean as necessary.

(3) Check the boiler stack temperature. If it is too high (more than 150°F above steam or water temperature) clean tubes and adjust fuel burner.

(4) The air-to-fuel ratio must be maintained properly. If there is insufficient air, the fire will smoke, cause tubes to become covered with soot and carbon, and thus lower heat transfer efficiency. If too much air is used, unused air is heated by combustion and exhausted up the stack, wasting heat energy. Most fuel service companies will test your unit free of charge or for a small fee.

(5) Inspect all boiler insulation, refractory brickwork, and boiler casing for hot spots and air leaks. Repair and seal as necessary.

(6) Clean mineral or corrosion buildup on gas burners.

(7) Replace boilers at or near end of useful life. A boiler at or near the end of its useful life should be replaced by a modern version which is matched to current and projected needs of the installation involved. In most cases new boilers on the market can obtain 80 percent efficiency. Even more efficiency can be gained by specifying multiple boilers and/or air-atomizing burners as appropriate. Replacement burners should be selected on the basis of long-term cost rather than first cost. Increased cost of fuel, labor and materials should be considered in developing long-term cost projections. Also consider installation of a dual-fuel system to avoid problems in the event of any shortages or curtailments.

b. Boilers (Fuel Oil)

(1) Check and repair oil leaks at pump glands, valves, or relief valves.

(2) Inspect oil line strainers. Replace them if they are dirty.

c. Boilers (Electric)

(1) Inspect electrical contacts and working parts of relays and maintain in good working order.

(2) Check heater elements for cleanliness. Replace them as necessary.

d. Central Furnaces, Make-up Air Heaters, and Unit Heaters

(1) All heat exchanger surfaces should be kept clean. Check the air-to-fuel ratio and adjust as necessary.

(2) Inspect burner couplings and linkages. Tighten and adjust as necessary.

(3) Check for oil/gas leaks.

(4) Inspect the casing for air leaks; seal the leaks.

(5) Adjust damper and draft regulation.

(6) Inspect insulation and repair or replace as necessary.

(7) Follow the suggested guidelines for proper fan and motor maintenance.

e. Radiators, Convectors, Baseboard, and Finned-Tube Units

(1) Inspect for blockage in front of the unit and remove any obstruction whenever possible. Air movement in and out of convector units must be unrestricted.

(2) Heat-transfer surfaces of radiators, convectors, baseboard, and finned-tube units must be kept clean for efficient operation.

f. Electric Heating

(1) Keep heat-transfer surfaces of all electric heating units clean and unobstructed.

(2) Keep air movement in and out of the units unobstructed.

(3) Inspect heating elements, controls, and, as applicable, fans, on a periodic basis to ensure proper functioning.

(4) As appropriate, check reflectors on infrared heaters for proper beam direction and cleanliness.

(5) Determine if electric heating equipment is operating at rated voltage.

(6) Check the control system for its proper operation.

2. Refrigeration equipment

a. Circuit and controls

(1) Inspect equipment for any visual changes such as oil spots on connections or on the floor under equipment.

(2) Observe the noise made by the system. Any unusual sounds could indicate a problem. Determine cause and correct.

(3) Establish what normal operating pressures and temperatures for the system should be. Check all gages frequently to ensure that design conditions are being met. Increased system pressure may be due to dirty condensers, which will decrease system efficiency. High discharge temperatures often are caused by defective or broken compressor valves.

(4) Inspect tension and alinement of all belts and adjust as necessary.

(5) Where applicable, lubricate motor bearings and all moving parts according to manufacturer's recommendations.

(6) Inspect insulation on suction and liquid lines. Repair as necessary.

b. Compressor

(1) Look for unusual compressor operation such as continuous running or frequent stopping and starting, either of which may indicate inefficient operation. Determine the cause and correct.

(2) Observe the noise made by the compressor. If it seems to be excessively noisy, it may be a sign of a loose drive coupling or excessive vibration. Tighten compressor and motor on the base. If noise persists, call a competent mechanic.

(3) Check all compressor joints for leakage. Seal as necessary.

c. Air-cooled condenser

(1) Keep fan belt drive and motor properly alined and lubricated.

(2) Inspect refrigeration piping connections to the condenser coil for tightness. Repair all leaks.

(3) Keep condenser coil face clean to permit proper air flow.

(4) Determine if hot air is being bypassed from the fan outlet to the coil inlet. If so, correct the problem.

d. Evaporative condenser

(1) Inspect piping joints and seal all leaks.

(2) Remove all dirt from the coil surface by washing it down with high velocity water jets or a nylon brush.

(3) Inspect air inlet screen, spray nozzle or water distribution holes, and pump screen. Clean as necessary.

(4) Use water treatment techniques if local water supply leaves surface deposits on the coil.

(5) Follow guidelines for fan and pump maintenance.

e. Watercooled condenser

(1) Clean condenser shell and tubes by swabbing with a suitable brush and flushing out with clean water. Chemical cleaning also is possible, although it is suggested that a water treatment company be consulted first.

f. Self-contained units (window and through-the-wall units)

(1) Clean evaporator and condenser coils.

(2) Keep air intake louvers, filters, and controls clean.

(3) Check voltage. Full rated voltage is essential for proper operation.

(4) Follow applicable guidelines suggested for compressor, air-cooled condenser and fans.

3. Humidification and dehumidification equipment

a. Remove lint and dust periodically from air dampers, fan parts, spray chamber and diffuser, controls, starter, and eliminator.

b. Check equipment for carryover. Carryover may be maintained by adjusting eliminator seal gap, altering damper position, or changing air velocity.

c. Follow guidelines suggested for fan and motor maintenance.

4. Air-handling equipment

a. Inspect ductwork for air leakage. Seal all leaks by taping or caulking.

b. Inspect ductwork insulation. Repair or replace as necessary.

c. Utilize ductwork access openings to check for any obstructions such as loose hanging insulation (in lined ducts), loose turning vanes and accessories, and closed fire dampers. Adjust, repair, or replace as necessary.

d. Inspect damper blades and linkages. Clean, oil and adjust them on a regular basis.

e. Clean or replace air filters on a regular basis.

f. Inspect air heating, cooling and dehumidification coils for cleanliness. Coils can be kept clean by using a mixture of detergent and water in a high-pressure (500 psig) portable cleaning unit.

g. Inspect for leakage around coils or out of the casing. Seal all leaks.

h. Inspect all room air outlets and inlets (diffusers, registers and grilles). They should be kept clean and free of all dirt and obstructions. Clean and remove obstructions as necessary.

i. Inspect air washers and evaporative air-cooling equipment for proper operation. Clean damper blades and linkages if so equipped. Inspect nozzles and clean as necessary.

5. Domestic hot water

a. Inspect water supply system and repair all leaks, including those at the faucets.

b. Inspect and test hot-water controls to determine if they are working properly. If not, regulate, repair or replace.

c. Inspect insulation on storage tanks and piping. Repair or replace as needed.

d. Consider replacing existing hot-water faucets with spray type faucets with flow restrictors where practical.

e. Consider installing spring-activated hot-water taps.

f. If water pressure exceeds 40 to 50 pounds, consider having a plumber install a pressure reducing valve on the main service to restrict the amount of hot water that flows from the tap.

g. If isolated cooking facilities are used only on occasion, as for conferences or meetings, deactivate the hot-water system, including the gas pilot if installed, when the facilities are not being used.

h. If hot water is distributed through forced circulation, turn off the pump supplying noncritical areas when they are unoccupied.

i. Disconnect all refrigerated water fountains if acceptable to building occupants.

6. Motors

a. Check alinement of the motor to the equipment driven. Aline and tighten it as necessary.

b. Keep motors clean.

c. Eliminate excessive vibrations.

d. Lubricate motor and drive bearings on a regular basis. This will help reduce friction and excessive torque which can result in overheating and power losses.

e. Replace worn bearings.

f. Tighten belts and pulleys to eliminate excessive losses.

g. Check for overheating. It could be an indication of a functional problem or lack of adequate ventilation.

h. Check for overvoltage or low-voltage condition on motors. Correct as necessary.

7. Fans

a. Check for excessive noise and vibration. Determine cause and correct as necessary.

b. Keep fan blades clean.

c. Inspect and lubricate bearings regularly.

d. Inspect drive belts. Adjust or replace as necessary to ensure proper operation. Proper tensioning of belts is critical.

e. Inspect inlet and discharge screens on fans. They should be kept free of dirt and debris at all times.

8. Pumps

a. Check for packing wear which can cause excessive leakage. Repack to avoid excessive water wastage and shaft erosion.

b. Inspect bearings and drive belts for wear and binding. Adjust, repair, or replace as necessary.

9. Hot and chilled water piping

a. Inspect all controls. Test them for proper operation. Adjust, repair, or replace as necessary. Also check for leakage at joints.

b. Inspect vents and remove all clogs. Clogged vents retard efficient air elimination and reduce efficiency of the system.

C. Energy Conservation Practices

A significant amount of energy can be saved by daily conservation practices which not only cut down on the amount of energy consumed, but also make the most of the energy that is used. The following energy-saving practices are grouped according to the areas where they are most likely to be used, such as in offices, housing areas, food service areas, public use areas and utility areas. Some of the more general items listed for one area may be applicable to other areas also.

Unlike the energy-saving measures described in the other sections of this handbook, implementing these conservation practices will require the participation of the full staff at the correctional facility. Assistance should be provided by facility management through policies supporting these conservation practices, and the development of incentives to encourage participation among facility staff and residents.

1. Administrative areas

a. In the heating season, place desks, tables, and work areas away from cold exterior walls.

b. Place desks, tables, and work areas where they can take advantage of natural heat and light from windows and skylights.

c. Consolidate heat-producing equipment (such as duplicating machines) to better control heating and cooling.

d. Consolidate work areas of after-hour workers to minimize the amount of space that must be heated, air-conditioned, and lighted.

e. Arrange to have janitorial work done during office hours to reduce the length of time the building is heated and lighted after working hours.

f. Coordinate after-hours janitorial services to minimize the time when different sections of the building must be lighted.

g. Where the administrative area is large and has several elevators, shut down some of them during nonworking hours.

h. Encourage workers not to leave equipment, such as typewriters, duplicating machines, coffee urns, etc., running when not in use.

i. Cover all window and through-the-wall air conditioning units when not in use. Specially designed covers can be obtained at low cost.

j. If outdoor awnings are used, install ones that are adjustable so that the sun can heat the rooms through the windows in winter.

k. Close blinds, shades, and drapes at night during the heating season to reduce heat loss through the window area. Open them during the day to use the sun for heating the rooms.

l. Close blinds, shades, and drapes during the day in summer. These interior shading devices can reduce heat gain in the room as much as 50 percent.

m. Post signs for personnel to remind them to keep windows and doors shut in areas that are being heated or cooled.

n. Preheat the building so that it achieves 5° below normal daytime temperature by the time people arrive, and finish warming up the building during the first hour of occupancy.

o. Don't keep buildings warmer than 55°F when unoccupied.

p. Begin precooling operations, so that the building is 85°F by the time people arrive, and finish cool-down during the first hour of occupancy.

q. Don't cool buildings when they are unoccupied.

2. Housing areas

a. Don't place lamps or TV sets near your air-conditioning thermostat. Heat from these appliances will cause the air-conditioner to run longer than necessary.

b. Run air-conditioners only on really hot days and set fan speed at high. In very humid weather, set the fan at low speed to provide less cooling but more moisture removal.

c. Lower the room thermostat setting to 50°-55°F when the fireplace is in use.

d. Take showers rather than baths.

e. Use cold water whenever possible when cleaning.

f. Use the dishwasher and washing machine only when there is a full load.

g. Air dry the dishes. After the final rinse on the dishwasher cycle, turn the control knob to the "off" position and open the door.

h. Dry clothes outdoors whenever this is practical. When the clothes dryer is used, dry laundry in consecutive loads. Stop-and-start drying uses more energy because a lot goes into bringing the dryer up to the desired temperature each time the machine is started.

i. Choose fabrics that require little or no ironing.

j. Place your refrigerator in the coolest part of the kitchen, well away from range or oven.

k. Defrost refrigerator or freezer frequently. Manually defrosting appliances use less energy than automatically defrosting ones, but must be defrosted frequently to maintain that edge. Frost should not be allowed to build up more than one-quarter of an inch.

l. Use long-life incandescent lamps only in hard-to-reach places. They are less energy-efficient than ordinary bulbs.

m. Try 50-watt reflector floodlights in directional lamps (such as pole or spot lamps). These provide about the same amount of light as the standard 100-watt bulbs but at half the wattage.

n. Turn off all lights when not needed. (One 100-watt bulb burning for 10 hours uses the equivalent of a pound of coal or one half-pint of oil).

o. Use fluorescent lights in suitable areas - on the desk, in the kitchen and bath, etc. They give more lumens per watt. One 40-watt fluorescent lamp provides more light than three 60-watt incandescent bulbs.

p. "Instant-on" television sets, especially the tube types, use energy even when the screen is dark. To eliminate this waste, plug the set into an outlet that is controlled by a wall switch; turn the set off and on with the wall switch. Or have a TV serviceman install an additional on-off switch on the set itself or in the cord to the outlet.

3. Food service areas

a. If cooking facilities are used only on occasion, install a local hot water supply system and shut it off when the facilities are not in use.

b. Exhaust hoods over ranges and grills should be no longer than necessary. Block off a portion of the hooded area if it is larger than needed. Use the exhaust only while cooking is underway.

c. Fans that cool workers should be directed so they do not cool cooking equipment.

d. Turn off infrared food warmers when no food is being warmed.

e. Reduce temperatures or turn off frying tables and coffee urns during off-peak periods.

f. Thaw frozen foods in refrigerated compartments.

g. Keep refrigerator and freezer doors open only as long as necessary.

4. Public use areas

a. In lobbies, corridors, and vestibules, shut off heating, cooling, and humidification.

b. If outside temperatures drop at night during the cooling season, use doors and windows or the ventilating system to flush the building with cooler outdoor air.

c. Schedule the use of meeting rooms to minimize energy spent to warm up or cool the space prior to use.

d. Make sure automatic door closers are working properly. Doors separating heated or air-conditioned space from space that is not heated or air-conditioned should be airtight and have automatic returns.

e. Periodically inspect automatic door closers, and gaskets on garages and other overhead doors to ensure they are working properly.

f. Where toilet facilities are used infrequently, couple the exhaust fan with the light switch so that inside air is exhausted only while the facilities are in use.

5. Water heaters

Reduce the temperature control setting of water heaters. Most heaters are set at 140°F or higher in the factory, which is excessive except for dishwashers. A setting of 120°F is generally adequate for residential use. A reduction in water temperature from 140°F to 120°F can save over 18 percent of the energy used at the higher setting. Even reducing the setting by 10°F will save more than 6 percent in water-heating energy.

6. Buildings and adjacent grounds

a. In areas of nearly constant strong winds, build or install wind screens perpendicular to entrances and walls having large window areas. These screens may be made of concrete block, wood, or other materials. They must be carefully positioned to avoid creating wind turbulence at doorways.

b. Install baffles to prevent wind from blowing directly into outdoor air intake structures of heating, cooling, and ventilating systems.

c. Insulate large exterior doors wherever possible.

D. Application At Correctional Facilities

Operation, maintenance and conservation practices once developed must be capable of being applied in the correctional setting. Previous discussion has addressed the role of staff and inmates in supporting the program, and the problems an administration will encounter in attempting to implement the program.

Prior to the actual application of the program, the following questions need to be answered:

a. What is the overall goal of the program? To reduce energy wastage, improve correctional environment, develop new sources of energy, etc.).

b. What organizational design (involving both staff and prisoners) will best meet the objectives of the program? Participative management, increased traditional control, etc.).

c. How can the institution change in response to needs and deficiencies identified by the initial energy survey?

By taking a critical look at these issues, the administrator, will understand that the energy program will not be an autonomous entity and it must, therefore, establish workable ties to other hierarchies that it is dependent on. Once these issues are addressed, the manager must specifically take into account the following factors:

a. Institutional staff may not be resistant to change, but may instead encounter a number of obstacles to implementation;

b. Staff are dependent upon formal and informal leaders who should be used to overcome obstacles;

c. Staff who are initially favorable to the program may later develop a negative attitude due to frustration encountered during implementation;

d. Lack of clarity about roles and responsibilities staff are expected to fulfill may cause confusion;

e. Unavailability of required materials and equipment may prove to be a major difficulty; and

f. Rewards may still favor old behaviors which run counter to the success of the program.

Finally, reflecting on the following questions can help identify potential application problems:

a. The cooperation of what other groups (Government, private) is likely to be needed for successful implementation?

b. Are there existing client groups whose interests will be adversely affected?

c. Does the energy conservation program threaten the job or status of someone who could block it?

d. Do existing staff and inmates have the motivation and interest to make the program work?

e. Does the program require different behavior and how realistic is this?

f. Does the program require space or facilities that may be difficult to acquire?

g. What events have taken place in the institution that are supportive or harmful to the program? and,

h. Has the program been discussed publicly? What effect will this have on acceptance?

CHAPTER VIII. ALTERNATIVE ENERGY SOURCES

A. Introduction

Alternative, or unconventional, energy resources promise to be, once again, the most important form of raw power used by Americans over the next few decades. Most of the new ways to produce power are a rediscovery of the old, proven methods that were abandoned after the discovery of the cheap, oil-based power have relied on for our energy needs since 1900.

In any discussion of the use of alternative energy, it is economics rather than technology which determines whether any given unconventional system is practical; the technology in most cases is becoming highly refined and generally widely available. It should be pointed out that most of these technologies are cost-effective and feasible today as sources of power when competing against the cost of electricity or oil in some regions of the United States.

The following information on alternative energy sources will allow you to make an informal decision as to the possible applications for such energy at your facility, the costs of obtaining this energy, and the ways to evaluate the use of conventional power versus alternative power in a given decision. This information is neither a complete coverage of these subjects nor a complete guide to the use of alternative energy.

B. Passive Solar Heating Systems

1. General Description. The most widely accepted definition of a passive solar heating and cooling system is one in which thermal energy flows through a building (from collection to storage to distribution) by natural means, enabling the system to function without external power. The operation of a passive system involves the control of the thermal energy flow and includes the ability to completely stop energy flow from escaping or entering the building (e.g., shading, insulation), and the ability to vary the timing or location of energy flow inside the building (e.g., opening or closing spaces to each other). Control of the system introduces a high level of design sophistication which is required in order to achieve the system's operational efficiency.

Both passive heating and cooling systems and their control operations can be inherent in the buildings' construction (for example, supporting walls which incorporate mass, insulation, and venting plenums), and in the buildings' organization (spatial hierarchy in response to energy flow tendencies). An efficient passive solar building will show understanding of the cyclic properties of existing climatic forces (sun times, wind location and speed) on a daily and seasonal basis.

The definition of a passive solar system, then, is determined by the dynamics of its operation rather than any static rules or any aesthetic image. This expresses a functionalist approach to architecture, in which the passive solar system is an intrinsic part of the building, and requires the designer to broaden his concept of the building.

To improve the efficiency of passive solar systems, it is sometimes helpful to assist the natural energy flow with mechanical means, a small fan for example. Where mechanical means are used to assist energy flow from the collector to storage or from storage to the conditioned space, but not both, the system is called hybrid, employing elements of both passive and active systems. It is based upon a separation of forced and natural energy flow, from the collector to storage or from storage to the conditioned space. When the energy flow is by natural means, it is a passive system. When either of the energy flows in the system, but not both, are forced the system is classified as hybird. And when all energy flow within the system is forced, it is classified as an active solar system.

2. Types of Passive Systems

a. Direct gain. The direct gain concept is the most common passive solar building solution and has many historic precedents. Simply diagrammed as sun to living space to storage mass, the solar radiation is collected in the living space and then stored in a thermal storage mass. Thus, the actual living space is directly heated by the sun and serves as a "live-in" collector.

(1) Requirements. The basic requirements for the direct gain building type are: a large south-facing glazed (collector) area, with the living space exposed directly behind; a floor and/or wall storage mass of significant dimension for solar exposure and for capacity; and a method of isolating the storage from exterior climatic conditions. For the first requirement, a large expanse of collector glazing, often double-glazing to minimize

heat loss, is oriented facing due south to admit the maximum useful radiation, while facilitating the prevention of solar gain in summer. In correctional facilities, the type of a glazing used should be carefully evaluated for the safety and security of the staff and inmates. Secondly, a considerable amount of thermal storage mass, in terms of walls, floors or free-standing mass, is incorporated in the building to store solar heat and provide longer term heating. The thermal storage mass of most prison walls enhances the possibility of storing the heat gained through additional glazing. Thirdly, the distribution of heat is controlled by the properties of the mass in relation to the space, and by insulation between the storage mass and the outdoors, or ground, which is critical in preventing unnecessary heat loss through temperature equalization.

(2) Variations. Beyond these basic requirements, there is a series of variations and controls that demonstrates alternatives in passive solar heating by direct gain. The most common variations are found in the location and the materials of the thermal storage mass. The best location of the storage mass is often decided by the physical laws governing natural heat flow by radiation and convection. For effective radiant distribution, physical proximity to the radiant body is an important factor in the location of the storage. Where convective air movements are caused by warm air rising, different temperature stratifications may also exist in a room, depending on the location of the storage mass. Typical location alternatives include the external building walls, the internal walls, the floor surface, and free-standing masses. In addition to storage location, there are significant variations in the storage materials, and the massing of those materials, which provide different heat capacities and different time lag properties. Storage materials vary from concrete, brick, sand, and ceramics, to water and other liquids, either singly or in various combinations, all radiating heat to the living space. The storage masses often incorporate circulation channels, plenums, or air spaces to improve the convective distribution of stored heat and provide a more sophisticated solar system with both radiant and convective heat contributions.

(3) Controls. To add to the efficiency and the usefulness of direct gain and other passive systems, several controls must be considered. To prevent unwanted heat gain, sunshading is required for the large expanse of south-facing glass. Due to the high location of the southern summer sun, overhangs can provide adequate protection for vertical southern glazing, but other solutions must be found for tilted glazing, or those with east and west orientations (faced with low sun angles). Exhausts and vents will also help cool interior spaces when summer temperatures are high. To prevent unwanted heat loss, insulation for the glazed collector area is necessary to improve the low U-value (resistance to heat transfer) of glass. Movable insulation panels, curtains, shutters, Skylids, or Beadwall, all work effectively to prevent unwanted heat losses on sunless winter days and nights, and will also prevent thermal heat gain on hot summer days. Without these control considerations, the addition of a passive system with its large glazed exposure to the outside and adjacent masses with great heat storage potential can cause tremendous discomfort due to winter losses and summer overheating, and greatly decrease the potential effectiveness of passive solar buildings.

b. Indirect gain. In the passive solar buildings that follow, the fabric of the prison continues to collect and store solar energy, but the sun's rays do not travel through the occupied space to reach the storage mass. This eliminates the direct gain temperature limitation whereby solar collection temperatures are limited by resident comfort needs. Thus, in the indirect gain concept, a storage mass collects and stores heat directly from the sun, and then transfers heat to the living space.

(1) Mass Trombe Wall.

(a) Definition. The first indirect gain passive solar building type is the Mass Trombe wall, in which the sun's rays are intercepted directly behind the collector glazing by a massive wall which serves as heat storage.

(b) Requirements and variations. The required elements of the Mass Trombe building type involve only a large glazed collector area and a storage mass directly behind it. However, the examples that follow display a variety of sophistications of the type. The range of storage materials identified in the existing Mass Trombe passive solar buildings includes concrete adobe, stone, and composites of brick, block and sand. A property to consider in deciding on storage construction is the method of distribution inherent in massing materials with different heat storage capacities and emission properties. Although this may not be a primary concern in prison design or construction, for passive solar applications, this should be a factor for consideration. Radiant distribution from a storage mass to a living space can be almost immediate, or it can be delayed up to 12 hours, depending on the depth and time lag property of the storage material chosen. Distribution of air by natural convection is also viable with the Mass Trombe system since the volume of air in the intervening space between glazing and storage mass is being heated to high temperatures and seeks constant means of escape. Through openings or vents at the top of the storage mass, hot air forces itself into the living space, drawing cooler room air through lower vents back into the collector air space. If the vents are controllable dampers, convective heat distribution can be shut off or started at will. Insulation placed between the storage mass and the living space can eliminate any direct radiation to the space, which controls distribution most effectively, but limits maximum thermal contribution. Distribution to and through the space, as well as storage construction, are variables which influence the Mass Trombe system's efficiency in operation.

(c) Controls. As in the direct gain building type, controls for the operation of the Mass Trombe building type are important, though less crucial since the living space is not directly influenced by solar gain. For optimum efficiency in the winter, external movable insulation, or other insulation alternatives, should be included to protect the storage mass from wasteful heat loss to the overcast or night sky. In the summer, unwanted heating of the storage mass should be prevented by shading the glazed area with overhangs, by closing the external insulation, or by external dampers and vents. A Mass Trombe wall has the potential to provide induced ventilation for summer cooling of the living space, by including exhaust vents at the top of the glazed area.

Solar heated air in the collector air space will force its way outside, drawing air from the living space to replace it. Therefore, another opening must be provided within the living space for replacement air - preferably from a shaded or cooler area. This continual air movement exhausts hot air from the house, drawing in cooler air for ventilation.

(2) Water Trombe Wall

(a) Definition. The second indirect gain passive solar building type is identified as the Water Trombe, in which the sun's rays are intercepted beyond the collector glazing by a water storage mass, then converted into heat and distributed by convection and radiation to the living space. The Water Trombe wall involves the same principles as the Mass Trombe wall, but employs a different storage material and different methods of containing that material. These variations offer a variety of methods for the integration of the Trombe passive solar concepts into the building vocabulary.

(b) Requirements and variations. The requirements for the Water Trombe wall are again a large glazed area and an adjacent massive heat storage. However, the storage is now water, or another liquid, contained in a variety of containers, each representing different heat exchange surfaces to storage mass ratios. Larger storage volumes provide greater and longer term heat storage capacity, while smaller contained volumes provide greater heat exchange surfaces and thus faster distribution. This tradeoff between heat exchange surface versus storage mass has not as yet been explored in depth. However, many container variations have been built, including components such as tin cans, bottles, tubes, bins, barrels, drums, bags, and complete water walls. The selection and interrelationship of storage materials, then, is necessary to the effective operation of the Water Trombe wall.

(c) Controls. In considering the control of heat distribution in a Water Trombe wall, one must be aware that thermal transfer is rapid within a convective body of water, and radiant distribution from a solar heated water storage wall to a living space is almost immediate. This is in contrast to the longer time lag property of the Mass Trombe wall. Therefore, if heat is undesirable until the cooler evening hours, the Water Trombe system requires some storage-distribution control. The addition of insulation between storage and the living space, combined with high and low vents for air circulation, provides one control solution, by allowing the system to rely solely on convective distribution. Aside from this distribution consideration, the controls for the Water Trombe wall are similar to those of the Mass Trombe wall. Overheating of the storage mass should be prevented by shading, and unnecessary heat loss from the storage mass should be prevented by exterior insulation. In addition, the use of operable vents which open to the outside, will induce summer ventilation as described for the Mass Trombe passive solar building.

c. Isolated Gain. In the isolated gain passive solar concept, solar collection and storage are thermally isolated from the living spaces of the building. This concept is contrasted with the direct gain passive solar concept where the collection and storage are integral with the living spaces, and with the indirect gain concept where collection and storage are separate from the living spaces but directly linked thermally. The isolated gain concept thus allows collector and storage to function somewhat independently of the building, while the building can draw from them as its thermal requirements dictate.

(1) Sunspace.

(a) Definition. The Sunspace isolated gain passive building type collects solar radiation in a secondary space which is separate from the living space, and also stores heat for later distribution. This "Sunspace" offers both the potential separation of the collector-storage system from the living space, or the direct gain "live-in" situation which maximizes the use of low temperature solar gain. Thus, in concept, a Sunspace passive solar system is midway between a direct gain system, in which the living space is the collector of heat, and a Mass or Water Trombe system, which collects heat indirectly for the living space. An atrium, a sun porch, a greenhouse and a sunroom all represent potential examples of a "Sunspace."

(b) Requirements and variations. The requirements for a Sunspace passive solar building type center on the glazed "collector" space which must be both attached yet distinct from the living space. Glazing must be selected which meets safety and security requirements at the prison. Provided with a strong southern exposure, the collector space must be thermally linked to a solar storage mass for heat retention and later distribution. The "Sunspace" can be variable in its spatial and functional relationships to the primary living spaces of the building. It may vary from a minimum addition to a building with one small contact surface, to extending the entire south side of the building, to being contained within the building with an interface on several sides. The specific location of the Sunspace will depend on the building design, spatial organization, and sun orientation. A storage mass is also necessary in the Sunspace type to retain heat for nonsunshine hours. Massive floors, walls, benches, rock beds, and covered pools of water can all provide effective solar heat storage, and could also be placed within reach of the winter sun for additional heat storage. If the Sunspace is to additionally serve as a greenhouse for growing plants, the temperature restrictions set for the direct gain type for comfortable living condition would be reestablished for the Sunspace type. In the case of an indoor swimming pool, storage temperatures must also be limited to meet swimmer comfort. Otherwise, the unoccupied Sunspace can store temperatures equal to the capacity of its storage materials, providing a controllable heat supply for the adjacent living spaces. When temperatures within the Sunspace are not too hot for comfortable "live-in" conditions, the Sunspace could then be occupied for more efficient direct gain heating.

(c) Controls. The most mandatory control consideration for this passive solar building type is the design of the link between the Sunspace and the living space. The 1, 2, 3, or 4 walls which interface a Sunspace and living space require built-in flexibility in order that these spaces can be thermally connected and separated as desired. In a prison environment, built-in flexibility to modify the living space may provide the largest impediment to this passive solar collection alternative. The kind of distribution, radiation, convection, or conduction, will be determined by these interfaces, and differentiate the Sunspace passive solar building type from the direct gain type. In addition, as in other passive solar building types, shading should be provided to prevent overheating of glazed spaces during the summer; and some form of movable insulation would prevent unnecessary heat losses on winter nights or cloudy days. Humidity control is also an important consideration to prevent molding within the storage mass in the plant or water occupied Sunspaces.

d. Thermospiphon (convection loop)

(1) Definition. The use of the Thermosiphon principle generates the fifth passive solar building type. It includes a collector space which intercedes between the direct sun and the living space, and is distinct from the building structure. A Thermosiphoning heat flow occurs when a cool air or liquid naturally falls to the lowest point (in this case below the collectors) and once heated by the sun rises up into an appropriately placed living space or storage mass, causing somewhat cooler air or liquid to fall again, so a continuous heat gathering circulation is begun. Since the collector space is completely separate from the building space, the Thermosiphon system begins to resemble the active systems frequently seen on today's market. However, no external power from fans or blowers are needed to move the heat transfer medium. The Thermosiphon principle has been applied in numerous solar domestic hot water systems, and offers equally great potential for space heating application.

(2) Requirements and variations. The basic elements of the Thermosiphon system include a collector space, usually a storage mass and a method of distribution. Solar heat is collected on a dark metal or wood absorber surface, heating up the adjacent fluid, which then rises naturally into a storage mass for convective or radiant distribution. In the Thermosiphon solar building type, the collector location is not fixed by the building and thus can take maximum advantage of sun exposure. Since the collector area is separate from the building facade, the house is also flexible in its wall and opening design. The solar storage mass can be located under the house floor, below windows, or in prefabricated wall elements. The storage locations and materials are the elements of most variation and offer building and system design flexibility. Distribution is provided by radiation from the storage mass and by convection (naturally rising air movements) from storage or directly from the collector, a variation which must be considered in the design stages. The spatial arrangement of the building is critical in providing effective heat distribution.

(3) Controls. In the Thermosiphon isolated gain building type, the link or contact area between the collector space and solar storage is not great, and can be easily blocked or disconnected to prevent air flow in adverse collector conditions (such as unwanted heat loss or overheating). However, controls must be carefully designed between the solar storage and the living space in order to meet the heating demands of the building and to prevent overheating. The area of interface between the storage mass and the building will determine the speed with which the living space can be heated through radiation and convection. On the other hand, the greater the contact area between the storage and the living space, the more crucial is the control against untimely or over-abundant space heating. For convective distribution from the storage mass of a Thermosiphon passive solar building, controls similar to those used in the Trombe building types are required, including operable dampers and insulation panels.

C. Active Solar Thermal Systems

Today the abundant energy available from the sun can be easily tapped by commercially available equipment. Solar energy has been known and used for thousands of years. There are three primary processes by which solar radiation is converted to useful forms of energy: solar chemical, solar electric, and solar thermal. In this chapter we will discuss solar thermal processes which can be utilized for domestic hot water, space heating, process heat, and other building thermal energy applications.

1. Required environmental conditions. There are two environmental conditions which are generally required for application of active solar thermal energy. They are the availability of a generally south-facing roof or other southeast-to-southwest piece of land large enough for solar collectors and a minimum of shading on the collector location due to obstructions between the hours of 10:00 a.m. and 3:00 p.m.

2. Production potential. Examining the potential production of proposed solar systems can require sophisticated procedures involving the use of computer simulation techniques that allow evaluation of the many different elements of the system, and the dynamics of their interaction over time.

3. Economics. Table 8-1 shows estimates of the current costs of typical thermal energy systems. If your application is atypical, a breakdown of the major solar component costs is also shown, to use for preliminary cost estimates. A reasonable cost division is 35 percent for collectors and supporting hardware, 20 percent for storage and heat transfer, 45 percent for all other mechanical and electrical components.

Table 8-1. Installed Solar System Costs

Small Building Retrofit Systems	Cost (1980)
Domestic hot water	$ 1,900 - 4,000
Hot water space heating	$ 8,000 - 20,500
Hot water space heating & domestic hot water	$12,000 - 22,000
Hot air space heating	$ 8,000 - 15,000
Hot air space heating and comestic hot water	$10,000 - 21,500
Solar greenhouse	$ 400 - 1,500
Solar assisted heat pump, and domestic hot water	$ 6,000 - 15,000
Small Building Components	**Cost per square foot of collector area**
Collectors	$ 10.00 - 20.00
Collector support structure	$ 3.00 - 10.00
Heat exchangers & collector fluid (liquid systems)	$ .50 - 1.00
Storage system	$ 2.00 - 5.00
Piping, valves, pumps, controls	$ 7.00 - 12.00
Large Building Retrofit Systems	**Cost per square foot of collector area**
Hot water	$ 40.00 - 50.00
Heating or heating and hot water	$ 50.00 - 60.00

D. Biomass

1. Introduction. Biomass, or the burning of plants, wood, garbage or byproduct materials such as bagasse is now recognized as an important source of energy. A plant is a biological solar collector which captures and stores sunlight by photosynthesis, creating a valuable source of renewable energy. Woodburning can be used with commercially available equipment for cooking, water heating and space heating, indeed nearly every application of stationary energy that fossil fuels now power.

2. Assessing the suitability of wood burning. In order to make a preliminary assessment of the suitability of wood combustion at your site, do the following:

a. Determine how much of your energy demand can be met from the combustion of wood. The amount of energy which can be produced is largely dependent upon the amount of wood available and the type of conversion technology used.

b. Determine the economic viability of wood combustion at your site. The economic viability of wood combustion is directly proportional to the available heat of the type of wood used and the conversion efficiency of the wood heater selected, and how well this compares to the present fuels being used in the building. Figure 8-1 presents the energy cost of various conventional fuels and their equivalent wood economics, for a preliminary assessment. The best way to find capital cost of the wood conversion technology you have chosen is to consult a local wood heater retail outlet. However, as an estimate a wood stove or furnace with an output rating of 60,000 to 70,000 Btu/hr costs between $500-$600. The cost of biomass combustion equipment is rapidly dropping as the large national demand creates economies of scale.

c. The next step is to calculate how huch energy the available biomass can produce. Table 8-2 shows the thermal energy contained in various types of wood (consult with the supplier for the energy content of other biomass) and table 8-3 indicates the conversion efficiencies of various combustion technologies. With this information you can calculate the total amount of energy available from a given amount of biomass.

E. Cogeneration

1. General. Cogeneration refers to multiple uses of a particular energy flow to produce more than one energy output, both of electricity and also process heat from the waste generator turbine steam. The basic principle used in cogeneration is the use of the waste energy from one energy-consuming process to drive another. Cogeneration involves getting extra use out of the same fuel, serving to increase the fuel conversion efficiency. Cogeneration was extensively used in this country in early years of American industry, and accounted for 22 percent of the total U.S. electric power in 1920, through recovery of industrial process waste energy. Later, cheap fuels available to our industries and utilities greatly reduced the use of this common-sense approach to power production. Now the escalating cost of fuel and energy are bringing back cogeneration as a viable option.

Table 8-2. Approximate Weight, Available Heat of Different Woods

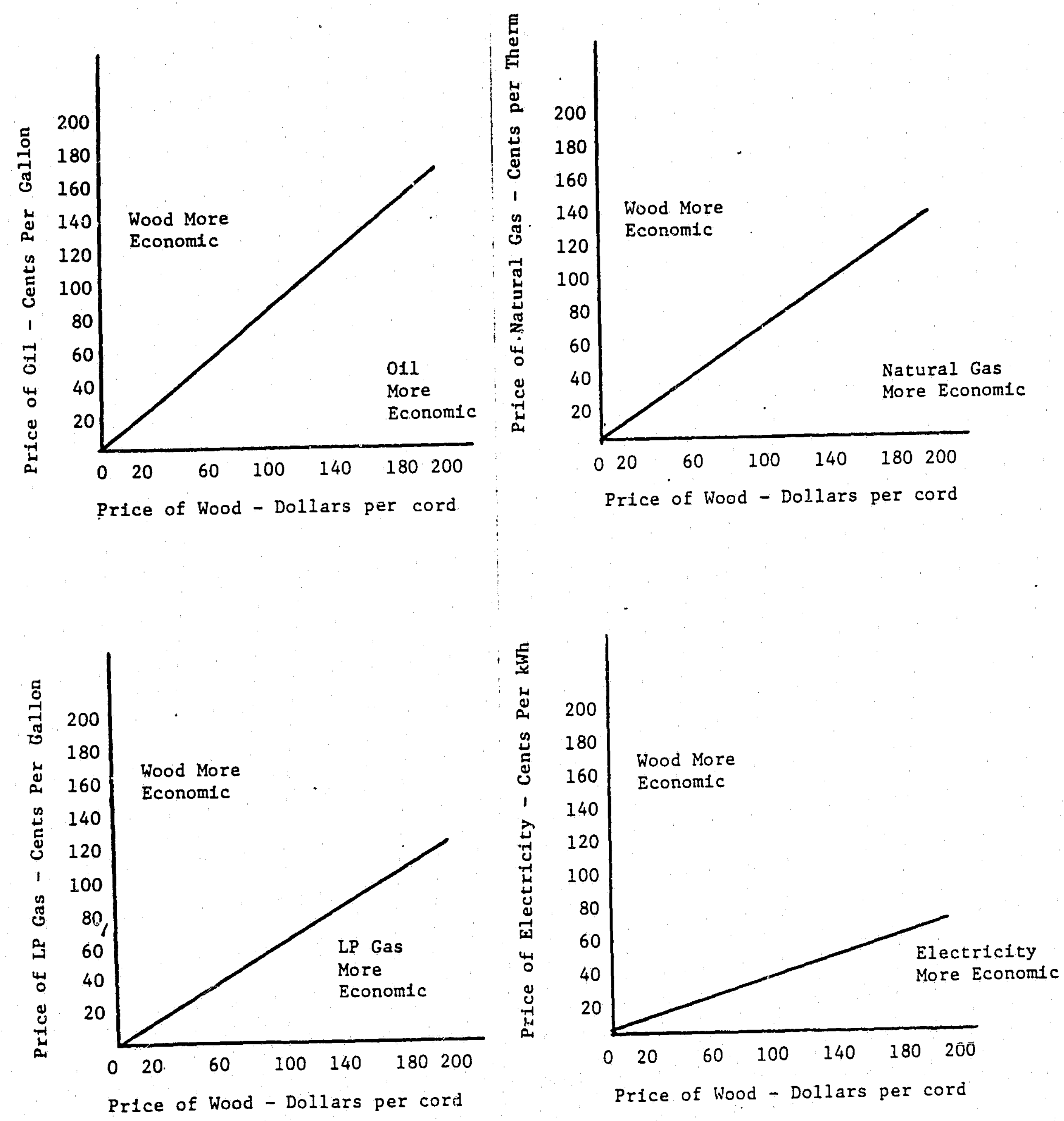
Type	Weight: Green Weight (lbs)	Weight: Air-Dry Weight (lbs)	Available Heat per Cord*: Green (MBtu)	Available Heat per Cord*: Air-Dry (MBtu)	Percent more Heat From Air-Dry %
Ash	3,840	3,440	16.5	20.0	21
Aspen	3,440	2,160	10.3	12.5	25
Beech, American	4,320	3,760	17.3	21.8	26
Birch, yellow	4,560	3,680	17.3	21.3	23
Douglas-fir, heartwood	3,200	2,400	13.0	18.0	38
Elm, American	4,320	2,900	14.3	17.2	20
Hickory, shagbark	5,040	4,240	20.7	24.6	19
Maple, red	4,000	3,200	15.0	18.6	24
Maple, sugar	4,480	3,680	18.4	21.3	16
Oak, red	5,120	3,680	17.9	21.3	19
Pine, eastern white	2,880	2,080	12.1	13.3	10
Pine, southern yellow	4,000	2,600	14.2	20.5	44

*Standard cord-to-stack 4 ft x 4 ft x 8 ft containing 80 ft^3 of solid wood.

Table 8-3. Wood Heater Efficiencies

Type	Efficiency
Masonry fireplace	15 - 35% efficient for continuous use; 0-14% most common
Metal fireplace	good designs may achieve efficiencies close to those of metal stoves
Franklin stoves	30 - 50%
Metal stoves	40 - 80%
Furnaces	40 - 80%

Figure 8-1. Energy Cost Comparisons



2. Application and required environmental conditions. The cogeneration of heat and electricity is the most practical means of using a given amount of fuel. Cogeneration spans the scale, from 15 kW residential units able to both heat and light a home, to 500 kW units for hospitals, schools, and small industry, to 70 megawatt units for large industry. Presently, only larger scale units (over 50 kW) are widely available. It is anticipated that in the next few years, smaller scale units and units with different energy outputs, such as a combination of electricity and cooling, will make cogeneration practical for very small applications. Though the principle of cogeneration is simple, selecting the exact system to meet your needs requires sophisticated and specialized engineering expertise. Therefore, the materials presented here can only be used to make a preliminary assessment. If you have a site that uses large amounts of building or process heat, you may well be able to use cogeneration. Make a preliminary assessment, then seek professional guidance.

The amount of electrical and thermal production is determined by site requirements: whether the site management wants to indigenously meet all or a portion of either its electrical and/or its thermal needs in this way. For example, a site manager may want to meet all of the facility thermal demands, and export surplus electricity, or may opt to meet the smaller electrical demand and compensate for thermal energy needs through another source, such as wood. The former option - exporting surplus electricity - demands a hookup to the electrical grid and an obligated utility.

3. Production potential. The technology of cogeneration differs in several important ways from the other sources of alternate energy. The fuel sources are conventional fossil fuels - diesel, gasoline, natural gas and coal. Selecting cogeneration equipment to retrofit an existing system or to install as a new system requires estimating both the electrical and heating output desired.

For most applications, the system will be sized to meet the heating requirements of the building, facility, or site. There is sufficient system design flexibility so that the resulting electrical output of the chosen system can meet all, most, or very little, of the electrical demand. If the cogeneration unit is bought as a package from a manufacturer, there is less choice regarding the level of electrical output at the corresponding thermal output. Most manufacturers will custom-design a cogeneration unit to meet any required specifications for any facility, however.

If the unit is chosen and sized primarily to meet the heating needs of a facility, there are three possibilities for the generated electrical output:

a. Electricity production will exactly meet the demand at the site. In this case, only an emergency backup generator or a small battery storage system would be required to supply power at times of peak demand.

b. Electricity production will be lower than the level of demand. Electrical needs will have to be met by a supplemental system such as the utility grid. This is the usual situation.

c. Electricity production will exceed demand. Surplus electricity is sold to the local utility and finances the fuel for the generator. In some cases the proceeds from sales of surplus electricity significantly reduce fuel costs. In others, the revenue will not only make the cogeneration unit competitive with the existing system, but will also add desirable extra capacity to the local utility.

If the unit is chosen to meet the electrical demand of a site, however, the reverse situation occurs. In most instances surplus heat is more difficult to market than surplus electricity. Furthermore, another heating system would have to be maintained. The second system would also operate at a lower efficiency than the cogeneration unit.

To make the preliminary assessment of a facility's cogeneration potential, you must be aware of both the heating and electrical requirements of your facility.

4. Economics. The following rough estimates can be used for a custom cogeneration system:

a. Cogeneration units cost approximately $400 per kW to install, regardless of size.

b. Cogeneration units rated under a million Btu/hr output cost $100,000 per million Btu/hr to install.

c. Cogeneration units rated at 100 million Btu/hr or greater cost $30,000 per million Btu/hr.

F. Application of Alternative Energy Sources to Correctional Facilities

The development of alternate energy sources in correctional institutions is an exciting concept. However, making such a development a reality requires several important steps:

1. Step 1 - Develop a list of energy sources for correctional facilities.

The selection process begins with a search for new sources of energy which can be used in a correctional setting. It is important to be creative and come up with as long a list as possible. Be careful not to screen out or criticize ideas at this point, that will come later. Also, do not limit the kinds of people from whom ideas are solicited. Industry supervisors, line staff, counselors and even residents should be queried.

Other sources of ideas include:

- Sources used by other correctional systems;
- Sources used by other public service agencies; and
- Sources used by private industry.

There are various methods that can be used to release or enhance the creativity of a group of people. Any of the following methods could be used to advantage in any group sessions designed to develop ideas for new prison energy sources.

a. Brainstorming. The rules for this group exercise are simple:

o No criticism--withhold judgments until later.

o Free-wheeling discussion - list any idea given.

o Large quantity - the more ideas the better.

To encourage additional ideas, the group leader should combine and improve ideas already listed.

b. Reverse brainstorming. The group develops a list of shortcomings in an existing energy source. This list provides the direction for new sources.

c. Attribute listing. The group lists the characteristics of an existing energy source. It then modifies the characteristics until a new combination emerges that will improve the source.

d. Forced relationships. The group lists new ideas and then considers them in pairs. By considering each idea in relation to every other idea, new energy source suggestions may surface.

2. Step 2 - Screen the ideas. If Step 1 has been done properly, a relatively long list of alternative energy sources should be available. The list must now be screened to come up with a small number which will be investigated in detail. The screening should be based on any or all of the following considerations.

a. Security. Certain sources may be too risky from a security point of view. What these sources are will vary from jurisdiction to jurisdiction and within a jurisdiction as policies change.

b. Skill levels. Some sources may be impractical in a prison environment because very high skill levels are needed to operate the source; very few prisoners have these skills or can acquire them in a reasonable length of time.

c. Resident and staff reactions. Alternate energy sources must operate in a highly volatile environment. It must be sensitive to and must take into consideration the reactions of both residents and staff who depend upon the source for, at least in part, heat, light, hot water, etc.

d. Costs. The costs of a specific source may be prohibitive given the initial start-up and operational costs in relation to savings in current energy costs. A source requiring substantial capital investment in equipment may be eliminated if capital is not available.

e. Safety/Health levels. Some sources may be ruled out because the cost of providing adequate, safe and healthy conditions created by the source is too high or because it would be impractical to enforce appropriate regulations in the prison setting.

f. Space. Certain sources are known to require large amounts of space. If prison space is at a premium, such sources may be ruled out.

g. Skill relevance. If the agency's goal is to provide inmates with a marketable skill, certain sources may be eliminated or retained.

3. Step 3 - Make a decision. A decision to proceed with development of a new energy source should be based on:

a. Finding a cost savings at acceptable input levels (capital investment, space requirements, security concerns, number of staff/residents required, etc.)

b. Sufficient potential to achieve at least cost savings equivalent to startup and operational expenditures.

c. A reasonable expectation that the payback needed to achieve at least break-even operations costs can be captured.

G. Correctional Facility Case Examples

1. Solar energy. The Federal Correctional Institution (FCI) at Bastrop, Texas, was planned for solar power. It opened in 1979 to house some 470 young adult male offenders in medium security. Four dormitories surround a large central building where, through Department of Energy aid, black chrome solar collectors ride south-facing roof slopes. The solar plant in the central building provides heated and chilled water for the central building and the dormitories, with hot water provided for cafeteria, laundry, and showers. The system produces 98 percent of the hot water, 66 percent of the hot air, and 8 percent of the cooling requirements for the institution.

FCI Otisville, NY., is among correctional facilities that manufacture solar collectors for sale to other institutions, the military, and private industry. So are FCI El Reno, OK., and state institutions in Florida and California. Water flowing through the light-receptive collectors is heated and used both for hot water supply and to transmit energy for other purposes.

Otisville, however, has gone a step further by building and utilizing photovoltaic cells, which generate electricity through the play of light on certain adjacent dissimilar materials. The photovoltaic plant powers shop tools in the plumbing and heating shop and is also available as an emergency lighting source for certain areas of the institution. The Otisville inmates recently refurbished a number of used golf carts and fitted solar receptors on their roofs to provide perpetual power through the trickle charging of the cart batteries. Significant savings are expected as the carts begin to replace automobiles for light transportation around the facility.

At Warwick, NY., the state's Mid-Orange Correctional Facility undertook a do-it-yourself solar conversion program without the Department of Energy aid obtained at Otisville. Philip Inger, an eighth-grade junior high science teacher, took a summer job at the prison as a vocational instructor and invited inmate-students to design solar energy systems for the prison.

Area citizens donated most materials and a resident sketched an air-heater type of collector which was built out of 78 coffee cans welded together and painted black. Another inmate built a model of a solar heater which is being constructed by his fellow residents using mainly donated scrap copper tubing. The Mid-Orange superintendent says the two panels will save 1,600 gallons of oil in a typical winter and he hopes to add other panels.

In California, the Rehabilitation Center at Norco developed a solar hot-water system as early as 1977 and thought of building solar collectors. "After studying it," a State Correctional Industries commissioner said, "we realized that what was really needed all over the country was people to install systems, not build them." Now 20 of the center's 1,550 inmates, including 2 of the 350 women, are learning solar installation.

In what may well be a very incomplete list, solar installers and technicians are also being trained at FCI Memphis, TN., and at state institutions in Florida and Connecticut.

One of the citizens involved in early planning for the new jail being built for Baltimore County, MD., was also a leading ecologist. At his insistence, the request for architectural proposals specified that the building's energy-consuming systems be solar-assisted. Collector panels stand out boldly in the successful architects' drawing of the modernistic new building.

The new Volusia Correctional Facility near Daytona Beach, FL., is designed for solar water heating. The system is estimated to cost $375,000, of which $225,000 goes for solar collectors.

At least two older Florida Correctional Institutes, Dade and Baker, are undergoing retrofitting to solar water heating for dormitories. Each solar panel system has a temperature differential controller to monitor storage and collector temperatures and to control the circulating pump accordingly. The Dade project is budgeted at $58,000 for construction, the Baker project at $95,000.

On October 1, 1980, the Georgia Department of Offender Rehabilitation (DOR) began a 1-year pilot program to train 45 inmates in various aspects of the manufacture, installation and maintenance of solar energy systems. The primary object of the $35,000 Comprehensive Employment and Training Act (CETA) program is to prepare offenders for careers in the rapidly expanding solar energy field. As part of the program, DOR's first solar energy system will be installed at Lee Correctional Institution (CI) in Leesburg, Georgia.

Initially, three facilities will participate in the pilot project. Metal collector pans will be manufactured by the metals vocational class at Georgia Industrial Institute, Alto, and delivered to the Macon CI.

Residents at Lee CI, specially trained in installation of solar heating systems, will install the collector panels on the two dormitories. An on-the-job training group at Lee CI will monitor and maintain the system.

2. Biomass. A lot of potential energy just gets thrown away. There are many ways of using organic material as an energy source which are beginning to creep into use in correctional facilities.

Arkansas, for example, plans to supply most of the heat for a new correctional institution with gases generated from the tons of hog manure collected from its state prison farm system.

The Georgia Department of Offender Rehabilitation plans the installation, in cooperation with Georgia Forestry Commission, of a wood-burning heating system at the new Central Georgia Correctional Center in Dodge County. The center, expected to open in 1982, will use wood chips from culled trees and possibly waste such as sawdust to generate steam for heating water and buildings. Since wood chips are cheaper than oil, natural gas or electricity, the system is expected to pay for itself within 6 to 10 years.

At Stillwater, MN, the Correctional Institute is using wood pellets to fire its furnace, having converted from coal. Wood from elms afflicted with Dutch elm disease is converted into the pellets, which produce about two-thirds as much energy per pound as coal and are considerably less expensive.

3. The warmth of earth. A new state high-security facility being built at Oak Park Heights, MN., will have its base and one side of the building built into the ground. Apart from the security aspects of the prison design, the under-earth construction will permit normal ground temperatures to assist both in heating and cooling the facility.

Further energy savings are expected through the use of a Delta 1000 energy management computer system for which the manufacturer, Honeywell, Inc., claims the following capabilities:

a. Evaluate building systems and assess energy consumption and operational conditions to pinpoint immediately any malfunction.

b. Perform preventive maintenance functions without manual operation of energy systems.

c. Maintain reports of energy consumption, thus providing further incentive for building supervision to maintain efficient operations.

4. Cogeneration. California has adopted a cogeneration blueprint for state facilities for implementation over the next decade designed to recapture the waste heat from electricity generation. The blueprint calls for the development of 400 megawatts of cogenerated electricity which it is expected will save 8.8 billion cubic feet of natural gas or 1.5 million barrels of oil annually. Additionally, the blueprint calls for the production of more than 2.4 billion kilowatt-hours of electricity annually, enough to supply up to one million new homes in California. The state conservatively estimates

the dollar savings from 400 megawatts of cogenerated electricity to be $140 million annually at today's energy prices. Over the life of the projects involved, it is estimated that the state will save seven dollars for every one dollar invested.

APPENDIX A

REPRODUCIBLE BLANK DATA FORMS

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WORKSHEET 1. ANNUAL ENERGY USE AND COST

FACILITY/BUILDING NAME: ____________________ CODE: __________ DATE: __________

LOCATION: ____

YEAR	ELECTRICITY			NATURAL GAS		FUEL OIL		COAL		OTHER:	
	MAXIMUM kW DEMAND	1,000 WATT HRS. (kWh) USED	COST ($)	NUMBER OF THERMS USED	COST ($)	NUMBER OF GALLONS USED	COST ($)	NUMBER OF TONS USED	COST ($)	QUANTITY USED	COST ($)

PRESENT COST OF ENERGY SOURCES ($/UNIT)

ENERGY SOURCE	$/UNIT	CONVERSION X FACTOR* =	MBtu
ELECTRICITY	/kWh		
NATURAL GAS	/THERM		
FUEL OIL	/GAL		
COAL	/TON		
OTHER:			

GROSS SQUARE FEET	

YEAR	NUMBER OF Btu USED PER YEAR PER SQUARE FOOT
BASE YEAR 1975	
PRESENT YEAR:	

*CONVERSION FACTORS: THE COMMON UNIT OF ENERGY MEASUREMENT IS THE BRITISH THERMAL UNIT (Btu), WHICH ARE THE UNITS USED LATER IN CALCULATING THE SAVINGS FROM RETROFIT PROJECTS. TO CONVERT ENERGY SOURCES TO Btu AND TO MAKE OTHER ENERGY CONVERSIONS, SEE APPENDIX B.

WORKSHEET 2. BUILDINGS IDENTIFIED BY SIZE AND CATEGORY

FACILITY: ______________________ DATE: ____________

BUILDING NAME OR NUMBER	APPROXIMATE SQUARE FOOTAGE	BUILDING CATEGORY	NOTES
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

WORKSHEET 3. CALCULATIONS

Facility: ______________________ Date: ____________

Building Identification: ______________________ Prepared by: ____________

Option No.: __________ and Title: ______________________

Work Description: ______________________

Energy Savings:

Cost Savings:

Capital Costs:

Simple Payback Period:

$\frac{\text{Capital Cost}}{\text{Cost Savings}} =$

WORKSHEET 4. RETROFIT OPTION COMPARISONS

Facility: ______________________ Date: ______________

Building	Option Number	Energy Savings		Energy Cost Savings ($/Year)	Capital Cost ($)	SPP (Years)
		Units / Year	MBtu / Year			

APPENDIX B

CONVERSION AND EFFICIENCY FACTORS

Table B-1. Conversion Factors

To Convert	Into	Multiply By
Barrels, oil	gallon	42.0
Cubic feet, natural gas	therms	0.01
Cubic feet, natural gas	Btu	1,030
Gallons, No. 2 oil	Btu	138,700*
Gallons, No. 4 oil	Btu	145,000*
Gallons, No. 5 oil	Btu	148,000*
Gallons, No. 6 oil	Btu	150,000*
Gallons, kerosene	Btu	135,000*
Gallons, gasoline	Btu	125,000*
Gallons, diesel oil	Btu	138,700*
Horsepower-hours	Btu	2,544
Horsepower-hours	kWh's	0.7457
Horsepower	Btu/min	42.4176
Horsepower (boiler)	Btu/hr	33,479
Kilowatt-hours	Btu	3,413†
Natural gas (1000 ft^3)	Btu	1,000,000
Short ton, eastern steam coal	Btu	23,100,000*
Short tons, western coal	Btu	21,000,000*
Short tons, anthracite coal	Btu	25,400,000*
Short tons, bituminous steam coal	Btu	21,600,000*
Short tons, lignite, brown coal	Btu	14,000,000*
Steam, saturated (lbs)	Btu	970
Therms, natural gas	cubic feet	100
Therms, natural gas	Btu	100,000
Tons, refrigeration	Btu/hr	12,000

*These are average values. Since exact Btu content varies with type and source, contact supplier when extreme accuracy is essential.

†When it is necessary to account for line losses and total Btu of the fuel used to generate electricity use 11,600. To account for line losses and total Btu of the fuel used to produce steam, use 1,390.

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Table B-2. Conversion Factors

These conversion factors should be used in completing Worksheet 1

To Convert $/unit shown into $/MBtu	Multiply By
Barrels, oil (dependent upon type of fuel oil)	-
Cubic feet, natural gas	9,800
Gallons, No. 2 oil	7.21
Gallons, No. 4 oil	6.89
Gallons, No. 5 oil	6.75
Gallons, No. 6 oil	6.66
Gallons, Kerosene	7.73
Gallons, gasoline	8.00
Gallons, diesel oil	7.24
Horsepower - hours	393
Horsepower - hours	218
Kilowatt - hour	293
Natural gas (1,000 ft^3)	.971
Short ton, eastern steam coal	.043
Short tons, western coal	.048
Short tons, anthracite coal	.039
Short tons, bituminous steam coal	.046
Short tons, lignite, brown coal	.071
Steam, saturated (lbs)	1,000
Therms, natural gas	10

Table B-3. Typical Energy System Efficiency Factors

A. External Systems	Efficiency Factor
Electric Generation (utility)	0.30
Electric Generation (on-site diesel)	0.30
Electric Generation (on-site gasoline)	0.20
Steam Generation (utility)	0.70
Steam or Hot Water (large boiler-gas)	0.90
Steam or Hot Water (large boiler-oil)	0.80
Steam or Hot Water (large boiler-coal or wood)	0.70
Steam or Hot Water (small boiler-gas)	0.80
Steam or Hot Water (small boiler-oil)	0.70
Steam or Hot Water (small boiler-coal or wood)	0.50
Hot Air Furnace (gas)	0.85
Hot Air Furnace (oil)	0.75
Hot Air Furnace (coal or wood)	0.60
Diesel Engine	0.35
Gasoline Engine	0.25
Gas Turbine	0.35

Table B-3. Typical Energy System Efficiency Factors (cont'd)

B. Internal Systems	Efficiency Factor*
Large Electric Motor (over 5 horsepower)	0.90
Medium Electric Motor (1/2 to 5 horsepower)	0.75
Small Electric Motor (under 1/2 horsepower)	0.65
Pumps*	0.70
Low Pressure Fans†	0.65
High Pressure Fans†	0.50
Air Compressor†	0.60
Steam Turbine	0.45
Storage Battery	0.75
Fan Coil Unit or Unit Heater*	0.35
	Coefficients of Performance (COP)
Heat Pump - Heating	2.25
Heat Pump - Cooling	2.50
Window Air Conditioner	2.00
High Efficiency Window Air Conditioner	2.75
Central Air Conditioner	2.50
High Efficiency Central Air Conditioner	3.00
Central Chiller Plant	3.50

*The efficiency factors apply to heating, water heating, and cooling systems. The options presented in Chapter V refer to this table as a source for these efficiency factors. Since some of the factors can be applied to more than one system (heating, water heating, or cooling), they have not been labeled as strictly a heating, water heating, or cooling efficiency factor. When used in equations, the factors are abbreviated -- HEF for heating, CEF for cooling, and WEF for water heating. The user must rely on his own judgment in choosing the type of internal system that best fits his environment.

†Includes motor, belt, and bearing losses where applicable.

GLOSSARY

GLOSSARY

1. Btu (British Thermal Unit) - a Btu is the amount of heat necessary to raise the temperature of 1 pound of water 1°F from 60° to 61°.

2. Kilowatt-hour - one kilowatt-hour (kWh) is equal to 1,000 watt-hours. One watt-hour is the amount of electrical power developed in a circuit by a current of one ampere flowing through a potential difference of one volt for a time period of one hour.

3. Kilowatt (kW) Demand - this is the instantaneous draw of electrical energy that is taken by a facility from a utility company or its own generating facility. The maximum yearly demand is the highest demand for a single month in a year. This can be found on the electric bill.

4. Load Factor - this is the total monthly kWh divided by the monthly demand and then divided by the total number of hours in the billing month. It is less than one and can be expressed as a percentage.

5. Power Factor - this is a highly technical term used to explain the phase relationship between the voltage and the current. A power factor of one is desirable. Electric utilities penalize users for a poor power factor.

6. Therm - a unit of heat which is equal to 100,000 Btu.

7. Kilovolt-Ampere (KVA) - KVA is similar to kilowatt demand except for the difference caused by the power factor. Called apparent power, it is calculated by dividing kW by the power factor.

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